New Scientist

WEEKLY 16 November 2024

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## Online event

### Best of *New Scientist*

Join us for a review of the biggest scientific stories of the year, as told by the team at *New Scientist*. Plus, put your questions to our expert panel of journalists about their favourite articles of 2024 and what they predict will be the big science stories of 2025 and beyond. This subscriber-only event starts at 6pm GMT/1pm EST on Tuesday 10 December.

**newscientist.com/events**

## Tour

### Science of astronomy and ice: Sweden

From striking alpine forests to picturesque snow-capped mountains, travelling to northern Sweden during the winter months offers a truly magical experience. Stay in a hotel made of ice and snow, visit Abisko National Park and travel to the Aurora Sky Station – one of the best places in the world to witness the aurora borealis. This four-day tour starts on 22 March 2025 and costs £3299.

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## Podcast

### Weekly

The team uncover the origins of cuneiform, the world's oldest writing system, and find out why researchers have been studying vampire bats on a treadmill. They check in with the world's largest tree, a quaking aspen in Utah called Pando. Plus, hear what to expect from the COP29 climate negotiations, which are under way in Azerbaijan.

**newscientist.com/nspod**

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**Aurora gazing** Learn about the phenomenon of the northen lights

RYHOR BRUYEU/ALAMY

**Fifty years of Lucy** Why was *A. afarensis* such an incredible find?

## Video

### AI on the silver screen

Hollywood has been imagining the impact AI might have on our lives for decades, but how accurate are these portrayals? AI researcher Beth Singler explores cultural depictions of technology, including AI, and how they might shape our fears and expectations. In this latest iteration of our sci-fi series, Singler dives into some of the best and worst examples of AI in film.

**youtube.com/newscientist**

## Newsletter

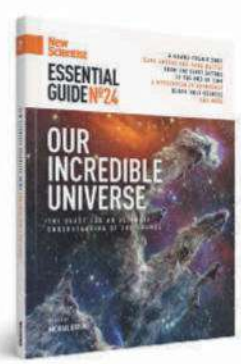
### Our Human Story

It has been 50 years since the Lucy fossil was found in Ethiopia. Michael Marshall considers why this archaeological find, which was given the scientific name *Australopithecus afarensis*, is so famous – not least because the unusually complete skeleton reveals things you can't see in most specimens.

**newscientist.com/our-human-story**

## Podcast

**"Vampire bats evolved to stalk prey on the ground and can run at least 30 metres a minute"**




## Essential guide

From tremendous chains of galaxies to supermassive black holes, our universe is a place of grandeur and spectacle. Find out how we are probing the cosmos like never before in this 24th *Essential Guide*, available to download in the *New Scientist* app or to purchase in print from our shop.

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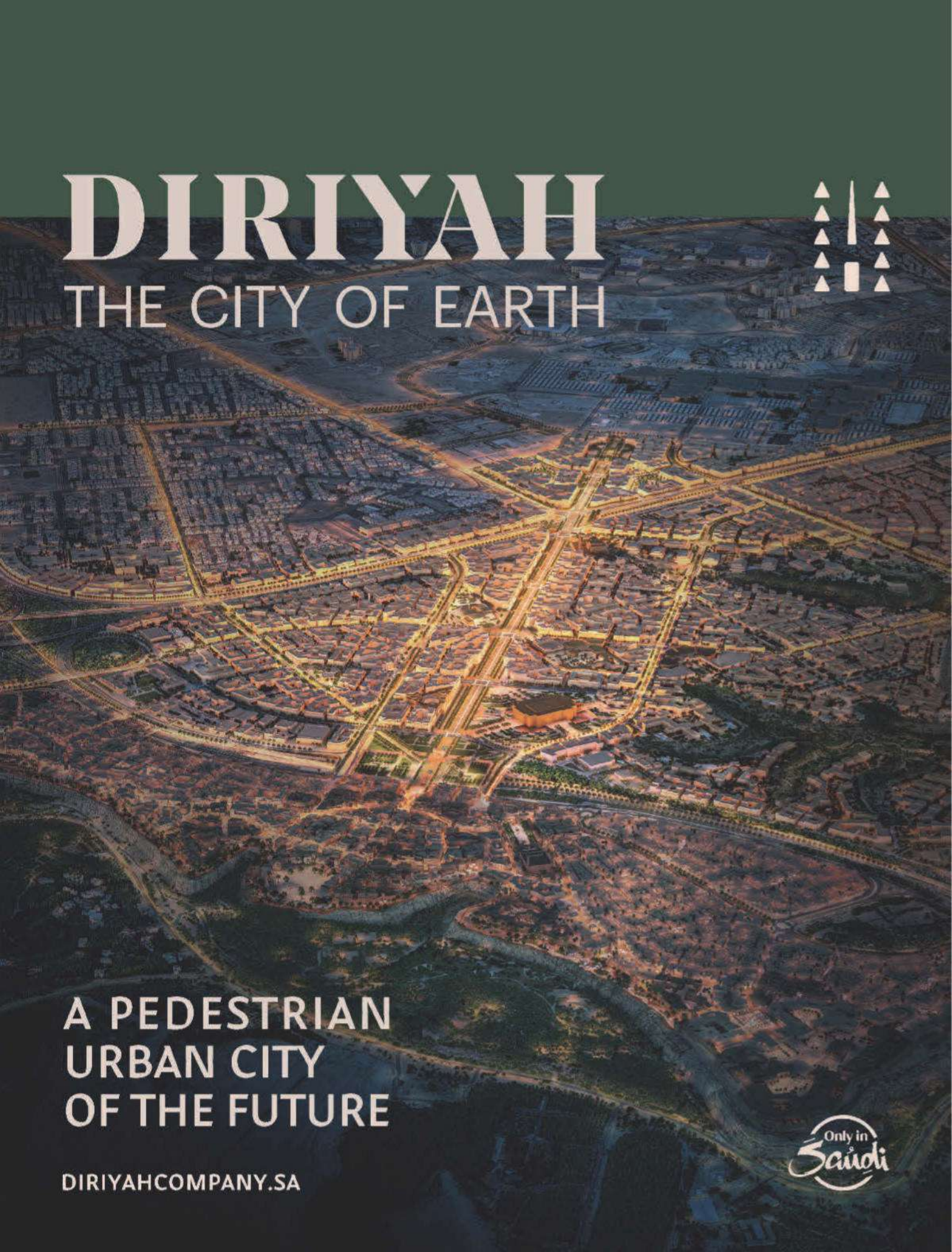
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# Crunch time

We need an all-out effort to avert the worsening food crisis

THERE are two monumental problems with the world's food system. Firstly, hundreds of millions of people can't afford to buy enough nutritious food to stay healthy. Secondly, it is incredibly destructive. We are still razing rainforests to make way for ranches, and both conventional and organic farms produce all kinds of pollutants, with food systems generating more than a third of greenhouse gases.

As the world soars past a 1.5°C rise in temperature (see page 8), things could get much worse. But there is plenty we can do, from eating less meat to reducing food waste (see page 44). With the amazing advances in genetic technologies in recent years, there is also huge scope to improve the plants and animals that provide our food. We can make them more nutritious, healthier, better able to cope with changing conditions and less susceptible to diseases that are thriving as the world warms. We should also be able to create plants that need less fertiliser and capture more of the sun's energy.

**"It is astounding that most countries aren't investing heavily in improving crops"**

The benefits from all this would be enormous: more food from less land, lower prices, reduced greenhouse gas emissions and less chance of viruses such as H5N1 bird flu causing another pandemic.

So it is astounding that most countries aren't investing heavily in improving crops. There is some private investment, but those companies are unlikely to make their technologies freely available, slowing their adoption.

We are also restricted by the notion that more "natural" means of farming are better, with opposition to genetically modified (GM) crops making it difficult and expensive to get them approved.

This is starting to change, with many countries making it easier for gene-edited crops and animals to get to market, but we need more action – and fast.

The idea that organic food is better for the planet and GM foods are worse for it is a false narrative that hides a much more unpalatable reality: that continuing as we are will lead to even more destruction and increased hunger. ▮

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# News


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ANATOLY MALTSEV/EPA-EFE/SHUTTERSTOCK

Environment

## COP29 opens in Azerbaijan

**The 2024 United Nations Climate Change Conference, COP29, hosted in Baku, Azerbaijan, has begun and will run until 22 November. World leaders from over 190 nations are expected to attend to discuss how to limit global temperature rise to 1.5°C and deliver money for emissions cuts. Hopes of a positive result don't seem high, however, partly due to the host nation's oil-production interests.**

Climate change

# 2024 set to be first year to hit 1.5°C

This year's average global temperature is almost certain to exceed 1.5°C above pre-industrial times, a milestone that climate experts say must spur urgent action. **Madeleine Cuff** reports

IT IS now almost certain that 2024 will be the first year on record to see average temperatures exceed 1.5°C above pre-industrial levels, breaching the threshold set by the Paris Agreement.

"At this point, barring an asteroid impact or a massive volcanic eruption... I think it's safe to say this will be the first year above 1.5 degrees," says Zeke Hausfather at US non-profit organisation Berkeley Earth.

Last year, the average global surface temperature was 1.45°C above the 1850-1900 average that acts as the pre-industrial baseline, with a margin of error of 0.12°C, according to World Meteorological Organization figures. Five main datasets are used to get this value.

All the pointers are that the final figure for this year will be even higher. For the first eight months of 2024, the average temperature surpassed that for the same month in 2023, says the US National Oceanic and Atmospheric Administration. The average for this period was 1.54°C above pre-industrial levels, according to data from the Met Office, the UK's weather service.

Although the average for September was cooler than at the same time last year, there is little doubt that 2024 as a whole will exceed the global limit for the first time. "It would take quite a notable and unusual cooling event to bring the annual average below 1.5°C," says Colin Morice at the Met Office.

Temperature datasets collected by various institutions around the world vary slightly, mainly due to differences in how ocean temperatures have been gathered and analysed over the decades.

But the five main datasets are set to indicate 2024 temperatures settled around 1.5°C above pre-industrial times, with several just above this mark, says Hausfather. "While not all of the datasets are going to be above 1.5°C this year, it is going to be the first year where the average... is above 1.5°C," he says.

The primary reason for rising global temperatures is human-caused climate change, says Carlo Buontempo at Copernicus, the European Union body that monitors climate. "This is not coming out of the blue," he says. "The main driver for this warming is increasing greenhouse gas in the atmosphere." A recent, strong El Niño pattern, the Pacific Ocean phenomenon that generally brings higher global temperatures, is another significant factor.

But the scale and persistence of the heat has shocked many scientists, who expected temperatures to subside once El Niño ended in May 2024. Instead, the record-breaking heat continued well into the second half of the year.

Competing explanations abound. The sun reached a so-called solar maximum in 2024, slightly increasing the solar radiation hitting Earth.

JHOJAN HILARION/AFP VIA GETTY IMAGES

Meanwhile, changes to shipping pollution rules in 2020 have reduced air pollution over the world's oceans, potentially magnifying heat absorption from the sun as certain pollutants are known to have a cooling effect.

But research into the impacts of these factors is still inconclusive, says Piers Forster at the University of Leeds, UK. "We do not completely understand why this extra spike in surface temperatures has continued," he says.

He warns it may be that the rate of climate change has accelerated. "If you just look at historical temperature changes, they do not increase in a monotonic way, they seem to go in fits and starts," he says.

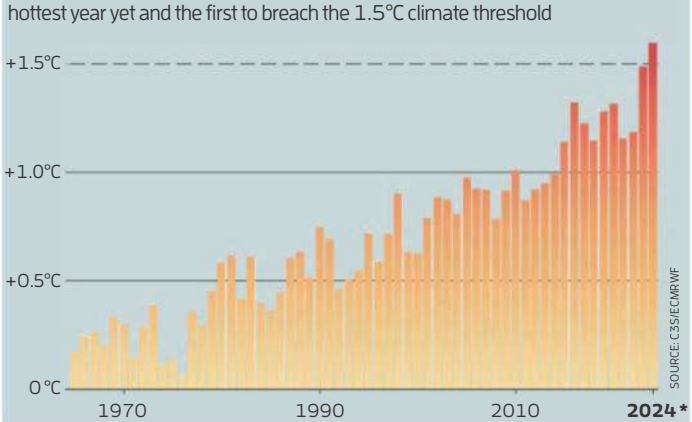
The world has already experienced a 12-month period above 1.5°C of warming, with temperatures between July 2023 and June 2024 being 1.64°C above pre-industrial levels, according to Copernicus. Still, the passing of the 1.5°C threshold in one calendar year is a totemic moment for the climate community. The limit has become a guiding light for it, after being included as a "stretch goal" in the 2015 Paris Agreement.

Yet years of failure to cut global emissions have made a breach almost inevitable, despite research since 2015 showing that warming beyond 1.5°C would be far more dangerous than first thought.

However, a single year above

## Breaking the limit

The rise of the annual global temperature above the pre-industrial (1850-1900) baseline has been fairly constant, but 2024 looks as if it will be the hottest year yet and the first to breach the 1.5°C climate threshold



Drought has shrunk Colombia's Guavio reservoir, which feeds a hydroelectric power plant

1.5°C of warming will not count as a breach of the Paris Agreement – which is judged on a 30-year average. On that basis, most climate models expect the 1.5°C threshold to be exceeded at some point in the early 2030s, unless the world makes immediate, dramatic emissions cuts.

Nevertheless, Hausfather hopes 2024 will underscore how fast the world is changing due to human activities. "Hopefully, it will serve as a wake-up call for policy-makers, and then history will look back on it as the year when the world changed and started finally taking this problem as seriously as it deserves," he says.

Forster echoes this sentiment, arguing it should spur leaders into taking action to cut real-world emissions and adapting societies to prepare for climate change. "I want to try as much as possible to connect this passing of 1.5°C with what we have to do to protect our society from the impacts of climate change," he says. ▮

# Any delay in reaching net zero will influence the climate for centuries

**DELAYING when we hit net-zero emissions by even a few years will have repercussions for hundreds of years, leading to warmer oceans, more extensive ice loss in Antarctica and higher temperatures around the world.**

**Nations have collectively promised to prevent more than 2°C of global warming, a goal that can only be achieved by reaching net-zero emissions – effectively ending almost all human-caused greenhouse gas emissions – before the end of the century. But once that hugely challenging goal is achieved, the planet will keep warming.**

**"Even if we do reach net-zero emissions – and that has to be a goal – we still have lots of aspects of the climate that are going to evolve for a very long time," says Andrew King at the University of Melbourne.**

**Climate scientists are using computer models that capture the way carbon is absorbed and released by land and the ocean to simulate how Earth's systems might respond to a stable, net-zero emissions world. Most such experiments model a net-zero world for about 100 years, but King and his colleagues have now simulated 1000 years of net-zero emissions.**

**The researchers modelled scenarios in which emissions continue to rise rapidly before reaching net zero at five-year intervals from 2030 to 2060. This resulted in seven separate simulations of net zero under different levels of warming.**

**They found that although warming over land stabilises once net zero is achieved, the deep ocean continues to warm for centuries, as heat from surface waters descends, pushing up global mean temperatures (*Earth System Dynamics*, doi.org/nrpc).**

**"The unfortunate thing is that we have changed the climate, and in some aspects it is going to keep going further and further away from its pre-industrial state for quite a long time," says King.**

**Certain parts of the world will experience more ongoing change than others. In the northern hemisphere, most land regions will reach peak warming within a few centuries of achieving net-zero emissions.**

**By contrast, the Southern Ocean will continue to warm for 800 to 900 years. This will lead to long-term decline in Antarctic sea ice over the centuries and more warming in Australia.**

**The later we achieve net zero, the larger these changes will be, suggest the simulations. Delaying net zero by just five years results in a warmer ocean, lower levels of sea ice and higher average temperatures around the world. For example, if net-zero emissions are reached in 2060, under a high-emissions scenario, the city of Melbourne will warm by a further 1°C after that point.**

**"The faster we get to net zero, the better," says King.**

Big wildfires have hit California this year – what would happen in even warmer conditions?

ABACA/SHUTTERSTOCK

**While some aspects of the climate system will keep changing after net zero, others appear to return to a pre-industrial "normal" in the simulations. In some areas, such as the Mediterranean, rainfall patterns return quickly to 19th-century levels. The El Niño and La Niña weather patterns, which have seen their heating and cooling effects strengthened by climate change, will also damp down once we reach net zero.**

**900**
years more warming could hit the Southern Ocean after net zero

**5 year**
delay in reaching net zero means higher average temperatures

**King cautions that the results are based on just one Earth system model. Nevertheless, Paulo Ceppi at Imperial College London says the results may enhance our understanding of how net-zero emissions will change regional climates. "I am sure there are some aspects here that would be robust across models," he says.**

**The simulations aren't direct predictions of a net-zero emissions future, though. For one, the model simulated emissions being cut to zero from high levels overnight, rather than a more realistic tapering over decades. "It's completely unrealistic to go to net zero overnight," says Ceppi.**

**The simulations also assume the world stays at net-zero emissions, but if efforts to remove carbon dioxide from the atmosphere continue, it may start to reverse some climate impacts.** ▮ **MC**

Technology

# Audio AI is also riddled with bias

Like their text and image counterparts, audio-generating AI models have issues

Victoria Turk

ARTIFICIAL intelligence models that generate audio are being trained on datasets plagued with bias, offensive language and potential copyright infringement, sparking concerns about their use.

Generative audio products, such as song generators, voice cloning tools and transcription services, are increasingly popular, but while text and image generators have been subject to much scrutiny, audio has received less attention.

To help rectify this, William Agnew at Carnegie Mellon University in Pennsylvania and his colleagues combed a year's worth of audio-modelling studies to spot common datasets used to train AI. In total, they found 175 datasets containing more than 680,000 hours of audio between them.

The team then conducted a more detailed audit on seven of the most commonly used datasets, which were mostly in English. These included voice recordings, such as sentences read by volunteers for the Mozilla Common Voice project, music recordings such as the Free Music Archive, and AudioSet, a set of 2 million 10-second YouTube clips.

**3**

**mentions of the word "men" in most of the datasets for each mention of "women"**

To investigate biases, the team obtained transcripts of audio that contained words, such as speech or song lyrics, and identified keywords. With the exception of Mozilla Common Voice, which was more balanced, the datasets used the words "man" or "men" more than three times as frequently as "woman" or "women". Across datasets, "man" was strongly associated with words like "war", "kill" and "history", while words associated with "woman" included "store", "mom" and "bitch".

Many other words linked with identity appeared infrequently, suggesting a lack of representation. "Muslim" appeared five to 10 times less than "Christian", while "non-binary" only occurred around 10 times in total.

The researchers also tallied instances of profanity in the text and found that two datasets in particular – Free Music Archive and LibriVox – contained many thousands of occurrences of racist and queerphobic terms.

LibriVox comprises audio readings of public domain texts, meaning that the vast majority are over 70 years old and are likely to reflect outdated views and language. "Cultural norms have shifted a lot," says team member Sauvik Das, also at Carnegie Mellon.

The team also found that phrases such as "all rights reserved" featured frequently in the datasets, suggesting they may contain significant amounts of copyrighted material (arXiv, doi.org/nrnq).

Kerry McInerney at the University of Cambridge says the work fills an important gap in ethical discussions about audio AI, which are currently dominated by fears over deepfakes being used to imitate a person's voice.

A risk of training AI models on audio datasets like those studied, she says, is that they could end up producing offensive content – repeating a slur, for instance. Context is key: a musician may reclaim a racial slur in a song, for example, but would AI systems understand that the same word isn't acceptable in other contexts, or perhaps for an AI model to produce at all? "I think there is a risk that they start using these kinds of terms unprompted or uncritically," says McInerney. ▮

Environment

## Sunscreen particles boost rice growth during heatwaves

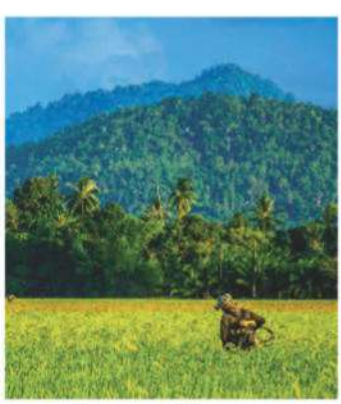
**A COMMON sunscreen ingredient, zinc nanoparticles, may help protect rice from heat-related stress, an increasingly common problem under climate change.**

**Zinc plays an important role in plant metabolism. A salt form of the mineral is often added to soil or sprayed on leaves as a fertiliser, but this isn't very efficient. Another approach is to deliver the zinc as particles smaller than 100 nanometres, which can fit through microscopic pores in leaves and accumulate in a plant.**

**Researchers have explored such nanoparticles as a way to deliver more nutrients to plants, helping maintain crop yields while reducing environmental damage from using too much fertiliser. Now Xiangang Hu at Nankai University in China and his colleagues have tested how zinc oxide nanoparticles affect crops under heatwave conditions.**

**They grew flowering rice plants in a greenhouse under normal conditions and under a simulated heatwave where temperatures broke 37°C (98.6°F) for six days in a row. Some plants were sprayed with nanoparticles and others weren't treated at all.**

**The average grain yield of plants treated with zinc nanoparticles was 22.1 per cent greater under heatwave conditions than the plants that hadn't been sprayed, and this rice also had higher nutrient levels.**



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Rice is a staple crop in much of the world, but the plants don't grow well in extreme heat

**The zinc was also beneficial without heatwave conditions – in fact, in these cases, the difference in yield between treated and untreated plants was even greater.**

**By measuring levels of nutrients in the leaves, the researchers concluded that zinc boosted yields by enhancing enzymes involved in photosynthesis, as well as antioxidants that protect the plants against harmful molecules known as reactive oxygen species (*PNAS*, doi.org/nrcw).**

**"Nanoscale micronutrients have tremendous potential to increase the climate resilience of crops by a number of unique mechanisms related to reactive oxygen species," says Jason White at the Connecticut Agricultural Experiment Station.**

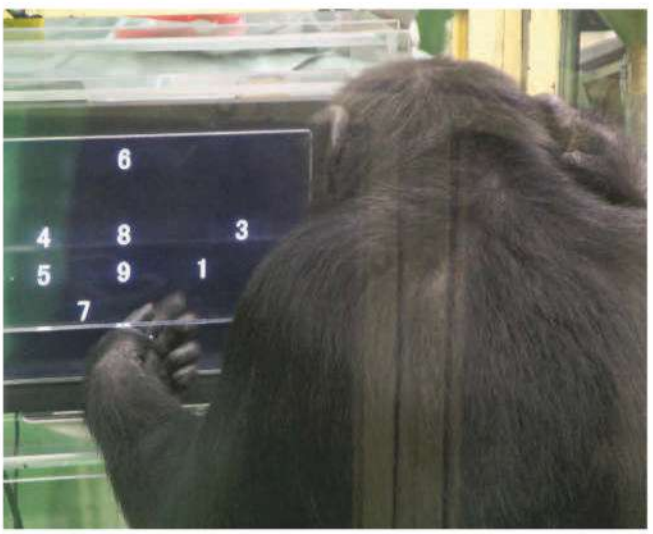
**Tests of zinc oxide nanoparticles on plants like pumpkin and alfalfa have also shown yield increases.** ▮

James Dinneen

Zoology

# Chimps do better at hard tasks when they have an audience

James Woodford




AKIHO MURAMATSU

A chimpanzee tackling a number selection test on a touch screen

THE pressure of a watching audience can have positive or negative effects on human performance, and it turns out the same is true of our closest relatives.

Christen Lin at Kyoto University, Japan, and his colleagues tested a group of six chimpanzees housed at the university's primate research institute on three numerical tasks with varying difficulty.

In the first task, the numbers 1 to 5 appeared on a screen in random locations and the chimps simply had to touch the numbers in the correct order to get a food reward.

In the second task, the numbers weren't adjacent: for example, 1, 3, 5, 7, 11 and 15 might appear on the screen. Again, the chimps had to press the numbers from smallest to largest in order to receive a reward.

Finally, in the hardest test, when the first number in the sequence was pressed, the rest of the numbers were hidden behind chequered squares on the screen. This meant the chimps had to memorise the location of the numbers in order to press them in the correct order.

The chimps were tested on the tasks thousands of times over a six-year period with varying audiences – from one to eight human observers, some familiar to the chimps and others who were new.

When the task was easy, the chimps performed worse when there were more people watching. But on the most difficult task, all six of the chimps did better as the size of the audience grew (*iScience*, doi.org/nrcv).

**"Such an audience effect is often thought unique to humans, who live in a reputation-based society"**

"It was very surprising to find a significant increase in performance as human experimenter numbers increased, because we might expect more humans being present to be more distracting," says Lin. "For the easiest task, the humans may be distracting to them, but for the most difficult task it is possible that the humans are a stressor that actually motivates them to perform better."

"Such an audience effect is often thought to be unique to humans, who live in a reputation-based normative society, where we sometimes perform better in front of an audience and sometimes perform worse than we expected," says team member Shinya Yamamoto, also at Kyoto University. "But our study shows that this audience effect may have evolved in the ape lineage before the development of this kind of normative society."

## Dangerous assumptions

Yamamoto says it is difficult and sometimes dangerous to draw direct implications for humans from non-human studies. "But, in a casual way, we may be able to ease the tension of those who are extremely nervous in public by saying chimpanzees are the same!"

Miguel Llorente at the University of Girona, Spain, suggests further studies could explore how the audience effect is related to chimpanzees' individual personalities.

"It would also be fascinating to explore these effects with chimpanzee audiences to understand more fully how these dynamics play out in a natural social context in order to generalise these results to the natural behaviour of chimpanzees," he says. ▮

Space

# Chinese rover finds more evidence for an ancient Mars ocean

**A POSSIBLE ancient shoreline has been found in the region of Mars explored by the Chinese rover Zhurong, providing further evidence that an ocean may once have covered a vast area of the lowlands in the planet's northern hemisphere.**

**The rover landed in the southern Utopia Planitia region of Mars in May 2021 and remained active for nearly a year. Researchers studying data from Zhurong have previously found hints of liquid water as recently as 400,000 years ago.**

**Now, Bo Wu at Hong Kong Polytechnic University and his colleagues have conducted a comprehensive analysis of the topographic features in the landing area, combining data from satellites with observations from the rover.**

**They say they have found features consistent with the existence of a shoreline in southern Utopia Planitia, including troughs and sediment channels. They also dated and identified the composition of surface deposits in the area. Based on this, they think the ocean existed 3.68 billion years ago, but froze and then disappeared 260 million years later (*Scientific Reports*, doi.org/nrbx).**

**"The findings not only provide further evidence to support the theory of a Martian ocean but also present, for the first time, a discussion on its probable evolutionary scenario," says Wu.**

**The area can be divided into a shallow section to the south and a deep section in the north. Even the shallow part of the ocean may have been up to 600 metres deep, says Wu, but there isn't enough data to estimate the maximum depth of the ocean.**

**"Water is a key ingredient for life, and the past presence of an ocean on Mars raises the prospect that Mars once might have been capable of harbouring microbial life at its early stage," he says.** ▮ JW

Health

# Bird flu antibodies found in US dairy workers without any symptoms

Grace Wade

THERE may be more bird flu cases in humans in the US than was previously thought. Health departments in two states took blood tests of workers on dairy farms known to have hosted infected cattle and found that about 7 per cent of them have antibodies for the disease. This included people who never experienced any flu symptoms.

Since March, a bird flu virus known as H5N1 has been circulating in dairy cows across the US. So far, 473 cows in 15 US states have tested positive for the virus. Since April, 44 people in the US have tested positive for H5 – the influenza subtype that includes H5N1. All but one of these cases occurred in workers on poultry or dairy farms with H5N1 outbreaks.

To better understand how many farm workers may have contracted the virus, the US Centers for Disease Control and Prevention (CDC) collaborated with state health departments in Colorado and Michigan to collect blood samples from 115 people working on dairy farms with H5N1-infected cattle. All of the samples were obtained between 15 and 19 days after cows on the farms had tested positive for the virus.

Nirav Shah at the CDC and his colleagues then removed seasonal influenza antibodies from the samples before testing them for the presence of H5N1 antibodies. They found H5N1 antibodies in eight of the samples, or about 7 per cent, suggesting that eight of the workers had been unknowingly infected with the virus. What's more, four of the workers didn't recall ever having symptoms.

**Bird flu has jumped from cows to some workers on dairy farms**

"This is critical because, before this point, the recommendations for [H5N1] testing largely have focused on symptomatic workers," says Meghan Davis at Johns Hopkins University in Maryland. "When workers don't know that they are infected, they inadvertently may expose other people in their communities to the infection."

H5N1 is poorly adapted to infecting humans and isn't known to transmit between people. Still, more than 900 people globally are reported to have had the virus since 2003, roughly half of whom died from it. Each infection offers the virus an opportunity to develop mutations that may make it more dangerous to people.

"We in public health need to cast a wider net of who we offer a test," said Shah at a press conference on 7 November. "Going forward, the CDC is expanding its testing recommendation to include workers who were exposed [to H5N1] and do not have symptoms."

The agency is also recommending that antiviral medications be offered to asymptomatic workers who have a high-risk exposure, like getting raw milk splashed on their face. "The less room we give this virus to run, the fewer chances we give it to change," said Shah.

The CDC is now analysing 150 blood samples collected from veterinarians who work with cattle. The results should provide a clearer picture of how many cases may be slipping through the cracks, said Shah. ▮

GRANT HEILMAN PHOTOGRAPHY/ALAMY

Animal behaviour

## Why wet hairy creatures feel the need to shake dry

**IF YOU have ever been close to a dog after it has gone for a swim, you have probably been sprayed with water flying from its fur. We now know the brain pathway that causes animals to rapidly wiggle themselves dry – a phenomenon known as the wet dog shake.**

**At least 12 different types of nerve cells help hairy mammals like mice and dogs feel physical sensations, such as temperature changes or touch. Yet it wasn't clear which of these neurons sense irritating substances that animals want to shake off.**

**To pinpoint the culprit, David Ginty at Harvard University and his colleagues placed a drop of cold sunflower oil on the back of the necks of 20 mice to elicit wet dog shakes. Twelve of the mice had been bred to have impairments in sensory neurons that respond to mechanical forces, such as pressure or stretch, meaning they couldn't feel physical touch. The rest of the rodents had impairments in cold-sensing neurons, so they could feel the droplet's pressure but not its chill.**

**Mice that could feel only cold didn't try to shake off the oil, but those that could feel only touch did. This suggests sensory neurons that respond to mechanical touch – not temperature – trigger wet dog shakes.**

**The team then placed an oil droplet on 17 different mice that didn't have any sensory impairments and monitored six different types of neurons that respond to mechanical touch. This revealed that three types of neurons activate during wet dog shakes.**

**Using a technique to switch cells on and off with light known as optogenetics, the researchers then activated each of these neuron types and found that one, called C-LTMRs, reliably produced wet dog shakes. Further experiments showed these neurons relay information to a brain region called the parabrachial nucleus, which triggers the animals to rapidly shake. Together, these findings map out the brain circuitry that causes hairy mammals to shimmy dry (*Science*, doi.org/nrb5).** ▮

**GW**

**12** types of neurons help hairy mammals feel physical sensations

Discovery Tours
NewScientist

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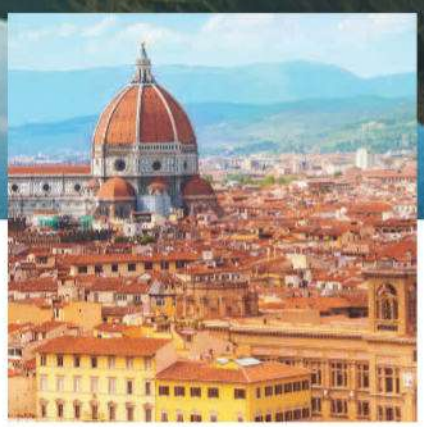

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Archaeology

# Ancient Egyptians shaped the horns of living sheep

Jeremy Hsu

**SHEEP with deformed horns are among the more mysterious animal remains discovered at an ancient Egyptian burial site dating back to around 3700 BC. They also represent the oldest physical evidence of humans modifying the horns of livestock.**

**"The sheep were deliberately made 'special' by castration," says Wim Van Neer at the Royal Belgian Institute of Natural Sciences. "In addition, their horns were directed upward, and in one case, the horns were removed."**

**Van Neer and his colleagues examined six sheep skulls found at the cemetery in the city of Hierakonpolis, which was a major political and population centre before kings ruled over a unified Egypt.**

**They found that three of the skulls have horns that point upward in parallel, rather than the typical horizontal spiral.**

**"It is unclear whether the sheep were meant as oddities or to look like another animal"**

**The horns of the fourth skull are less upright, but are closer together at the base than usual. A fifth sheep skull had its horns removed entirely, and a sixth one had horns extending horizontally in the natural way.**

**Impressions on the modified skulls and horns suggest that ancient Egyptians used ropes to bind the sheep's horns and bring them closer together as they grew. Holes in the skulls also suggest that people intentionally fractured the base of the horns before attaching bindings to direct horn growth vertically (*Journal of Archaeological Science*, doi.org/nrbm).**

B. DE CUPERE

A sheep skull modified so that the horns grew up instead of outwards

**The "rather precise and symmetrical treatment of the horns" indicates that the Egyptians "were not new to this practice", says Zdeňka Sůvová at Charles University in the Czech Republic. The modified horns would have also made the "already huge rams look even bigger", she says.**

**The sheep lived to a relatively old age before being sacrificed for burial in graves surrounding the tombs of presumed elite people at Hierakonpolis, along with other domesticated animals and even wild animals such as baboons and elephants. The sheep skulls predate other physical evidence of livestock with modified horns, such as cattle skulls found at an ancient site in modern-day Sudan, by around 1000 years.**

**But it is unclear whether the sheep were meant as oddities for display or were modified to look like another animal, such as an antelope. The researchers hope to find more ancient skulls with deformed horns from other livestock, which could help reveal the purpose behind the practice.** ▮

Physics

# Knots made in a quantum fluid can last forever

Karmela Padavic-Callaghan

BY MANIPULATING a quantum fluid, researchers could form liquid knots that never unravel. These may help us shed light on odd quantum objects from the dawn of the universe.

When tiny whirlpools called vortices form in a fluid, they can make loops that can then be knotted like a loop of string. While a string can form knots that won't unravel without the help of scissors, knotted vortices in a fluid break free more easily. They can explode into a diffuse swarm of vortices, or the liquid "strings" can pass through each other and re-form on the other side. Toni Annala at the University of Chicago and his colleagues realised that this could be prevented by going quantum.

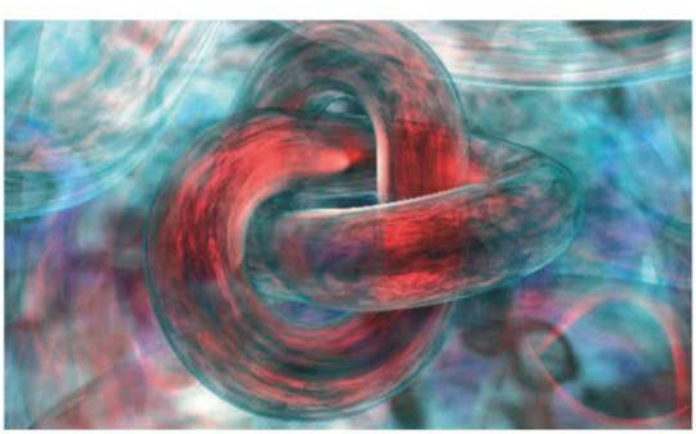
They have proved that certain knots – a trefoil, a figure of eight and a knot called Solomon's link – would be incredibly stable if created from vortices in a fluid that displays quantum effects, specifically one called a Bose-Einstein condensate (BEC). A BEC is made from atoms almost as cold as absolute zero, which stops them acting like particles and makes them behave more like a wave.

**Certain knots, like this trefoil, can be formed from vortices in a quantum fluid**

Because fluids like BECs display this quantum waviness, they must be described with mathematical equations that are more complex than those that apply to ordinary fluids such as water. And these equations contain rules for what a vortex can, and can't, do. The researchers determined that for atoms with a high value of a property called quantum spin, those rules could make vortex knots that are impossible to unravel (*Physical Review Letters*, in press).

Team member Mikko Möttönen at Aalto University in Finland says that actually making one of these knots in an experiment will require lots of technical expertise and innovation, but the researchers have been involved in similar experiments before and are sure there is a way forward.

"The mathematics is very, very generic [here], which means that if we can learn about it in the experimentally accessible BEC, that [knowledge] could then apply to systems that we can't bring into the lab," says Magnus Borgh at the University of East Anglia in the UK. Implications could go as far as learning more about theoretical vortex-like objects in the early universe, he says. ▮



CAROL AND MIKE WERNER/ALAMY

Physics

# Solving a quantum Rubik's cube

A new version of the popular puzzle would be far more difficult – but not impossible

Karmela Padavic-Callaghan

A QUANTUM Rubik's cube would be infinitely more complex than the traditional puzzle, but mathematical modelling shows it wouldn't be unsolvable.

In 2022, Noah Lordi and Maedée Trank-Greene at the University of Colorado Boulder and their colleagues made a bet: how many possible states would a quantum Rubik's cube have? To even make their guesses, they first had to define what a quantum Rubik's cube would entail.

An ordinary Rubik's cube has six sides divided into a grid of nine squares, each of which is one of six colours, resulting in more than a billion trillion possible configurations. In the quantum version, the researchers replaced each coloured square with a different type of particle. Their puzzle wasn't quite a cube: it was two particles tall and wide and one particle deep. To solve either puzzle, similar squares – those of the same colour or particle type – must end up together on a face of the cube.

These particles are moved around in the quantum puzzle in a similar way to how the coloured squares are moved to different sides of the cube in the traditional game, but the researchers also added a fundamentally quantum move. Here, two particles can be put into a superposition – simultaneously left in place and having their positions swapped.

SHUTTERSTOCK/SHINPANU

**Even solving a traditional Rubik's cube can be a challenge**

With the rules in place, it was time to bet. Each team member gave the highest number of configurations they thought possible. At one point, the largest was 20,922,789,888,000, but Trank-Greene upped the ante, guessing the possibilities were infinite. The team found that the addition of superpositions made her right (arXiv, doi.org/nrb4).

But Lordi says this didn't make the quantum Rubik's cube unsolvable. Borrowing methods from mathematics and quantum computing, the team determined that a specific sequence of moves for solving the quantum puzzle exists. However, while the record for solving a traditional Rubik's cube is just over 3 seconds, Lordi says the quantum version may take a finite but unimaginably large amount of time. "I could give you a scramble that takes 20 million moves to solve," he says.

The way out of this problem is to add another fundamentally quantum move. The researchers calculated what would happen if players were allowed to perform a measurement, which changes the quantum state of the puzzle. This process is probabilistic, so playing a measurement move won't always result in the Rubik's cube being solved and will sometimes mean that the puzzle needs to be re-scrambled. But over many games, a player could learn to employ it in such a way that they solve the puzzle most of the time. In this sense, a classical Rubik's cube champion and a quantum Rubik's cube champion would have to develop very different strategies, says Lordi.

**3 seconds**
**The record for completing a standard Rubik's cube**

Playing the quantum Rubik's cube can also be viewed as a quantum computing problem with digital quantum bits. Enrico Prati at the University of Milan in Italy says that this could make it useful for developing quantum simulations. ▮

Zoology

## Elephants use a hose to shower and to prank each other

**SOME elephants have become masters at using a hose – considered a complex tool because of its flexibility, length and the physics of flowing water.**

**Researchers studying three Asian elephants (*Elephas maximus*) at Berlin Zoo were surprised to see how nimbly they manipulated a hose to shower themselves and seemed to understand how to use it. They even appeared to play pranks on each other by stopping the flow mid-shower – either by kinking the hose or compressing it with their trunks.**

**To reach more distant parts of the body, the elephants used a lasso-like technique, holding the hose further from the end and swinging it over their backs.**

**Michael Brecht at the Humboldt University of Berlin says the animals' behaviour around hoses reminded the team of the way children might play together.**

**"Elephants are exceptionally good with hoses and we very much wonder if this is related to the functional similarity of trunks and hoses," he says.**

**Just as humans are either left-handed or right-handed, African and Asian elephant individuals are either left or right "trunkers", preferring to bend their trunk in one direction.**

URBAN ET AL. (2024)

Asian elephant Mary using a hose to shower the left side of her body

**The researchers noticed that the elephants also had a side preference when they manipulated the hose. One of the elephants, named Mary, used her trunk for showering the right side of her body but used the hose more for the left side.**

**Another of the elephants, Anchali, showed five different behaviours to disrupt water flow when Mary was trying to shower – hose positioning, lifting, kinking the hose, regrasping the kink and compressing (*Current Biology*, doi.org/nrpj).**

**"This sabotage-like behaviour, if that's what it is, has been seen in only very few animals," says Brecht. "The research reiterates the idea that elephants show very sophisticated trunk behaviours."** ▮

James Woodford

# New Scientist

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An MSF surgical team at Al-Shifa's burn unit in Gaza city cleans the wound of a child after a burn injury. Photograph © Tetiana Gaviuk/MSF

**DR JAVID ABDELMONEIM IS AN MSF DOCTOR RECENTLY RETURNED FROM WORKING IN GAZA.**

"At Nasser hospital, we provide trauma surgery and burns care to patients. One Saturday early in my time there, we received hundreds of injured, as well as people who had been killed, following a missile strike.

It was chaos. Our team went to the emergency room. One of the injured was a three-year-old girl. She was breathing and looking at me – so she must be okay, I thought. But as I rolled down her dressing, I found that her entire left thigh was open to the bone.

Seconds later, the doors crashed open. Four to five injured people were brought in, most of them first-aid responders. Among them was a boy who wasn't breathing, so we tried to revive him, but the nurse looked at us and asked: 'Why are we responding to him if he can't breathe? We have to save other lives.' No one had the heart to call it and move on to the next person. He was someone's child. But we had to move on to the next, and then the next, and this continued for another four and a half hours.

In the emergency room, there was blood all over the floor. I had to kneel to see the patients, who were sprawled everywhere because there were no beds left. At the same time, more and more patients were coming in.

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**MSFR0048**

Health

## More people now live with pain than before pandemic

Carissa Wong

CHRONIC pain has become more common since covid-19 emerged in 2019, and long covid only accounts for some of the rise.

Anna Zajacova at Western University in Ontario, Canada, and Hanna Grol-Prokopczyk at the University at Buffalo in New York analysed data from the US National Health Interview Survey, carried out in 2019, 2021 and 2023. In each year, a different group of about 88,000 adults was asked to report on experiences of chronic pain.

About 21 per cent of people had chronic pain in 2019 and 2021. But in 2023, that rose to 24 per cent. Extrapolated to the entire US population, this is equivalent to 10 million more adults experiencing chronic pain in 2023 compared with 2019, says Zajacova.

This rise applied to discomfort across most of the body, such as headaches and back, shoulder, neck and abdominal pain. Only tooth and jaw pain didn't increase, but it is unclear why they were the exception.

The researchers also found that 7.5 per cent of people reported having chronic pain that interfered with everyday activities in 2019, which had increased to 8.5 per cent by 2023 – resulting in an additional 2.6 million US adults being affected, says Zajacova. These effects rose similarly across men and women and people of different ages (medRxiv, doi.org/nq74). "We found a very broad impact," says Zajacova.

Based on long covid data, the researchers estimate that around 15 per cent of the increase in chronic pain was due to the condition, which can have pain as a symptom.

Other pandemic-linked changes may account for the rest of the rise. "If you are socially isolated through covid-19 measures and you have poor access to pain management, acute pain is more likely to become chronic," says Chris Eccleston at the University of Bath, UK. ▮

Archaeology

# DNA analysis rewrites the stories of people buried in Pompeii

James Woodford

ARCHEOLOGICAL PARK OF POMPEII

**Plaster casts of people who died in Pompeii when Vesuvius erupted**

POMPEII'S plaster cast human figures aren't who they were assumed to be, genetic tests have revealed, highlighting the way idealised stories can be projected onto archaeological evidence. The analysis also shows that the demography of Pompeii was far more complicated and diverse than previously thought.

When Vesuvius erupted in AD 79, it buried several Roman towns, including Pompeii. Many of the town's residents were completely smothered in compacted ash during the eruption and, as their bodies decayed, cavities formed that perfectly preserved their positions in their final moments.

In the 19th century, archaeologists developed a method of pouring plaster into the cavities to make life-like casts. Since then, more than 100 of these casts have been made, preserving the victims' shapes along with any remaining bones that hadn't decayed over the centuries.

However, it has long been known that many of the plaster casts were manipulated into different poses and sometimes placed together to add to the drama of the Pompeii story, says Valeria Amoretti at the Archaeological Park of Pompeii in Naples, Italy.

To learn more about who these people were, Amoretti and her colleagues examined 14 of the plaster casts and extracted DNA from the bones preserved in five of them. What they found has completely altered the established interpretations of who these people were and their relationships to each other.

> "Many of the plaster casts were manipulated into different poses to add to the drama of the story"

In one case, an adult wearing a golden bracelet with a child on their lap was long believed to be the child's mother (see picture, above right). The DNA analysis shows the adult is actually a male who is biologically unrelated to the child. A nearby figure, formerly interpreted as being the father, was also unrelated to the supposed mother and child.

Another pair, who were thought to be sisters or a mother and daughter who died in an embrace (see picture, above left), included at least one genetic male and were also unlikely to have been related.

The genetic analysis further revealed that the people of Pompeii had diverse ancestry, with components related to modern eastern Mediterranean, Levantine and North African Jewish populations (*Current Biology*, doi.org/nq84).

Amoretti says it is no surprise that the Roman world was multicultural, and that the Mediterranean and its ports united people. "But it is extremely interesting to discover the extent of this melting pot, even in an average provincial town like Pompeii, and to have scientific proof of it from ancient DNA," she says.

Alissa Mittnik at Harvard University says this highlights the importance of applying science before interpreting archaeology at face value. "Ultimately, it reminds us that the most intuitive, dramatic or sensational explanations do not always hold true, encouraging us to stay aware of and question our preconceived notions," she says. ▮

Biology

# Marmots may have the solution to a long-running debate in evolution

Michael Le Page

FRIENDLY groups of marmots could help settle an enduring debate in evolution – whether the characteristics of a group can be more important to an individual's chances of survival than the characteristics of that individual. An analysis of their behaviour is the first evidence in wild animals for this evolutionary idea, known as multilevel selection.

"What we found is that the group traits are under just as strong selection as the individual traits, if not slightly stronger," says Conner Philson at the University of California, Los Angeles. "So the group matters just as much, if not just a little bit more."

Evolutionary fitness is often portrayed as being about an individual's strength or ability to fight. But biologists from Charles Darwin onwards have realised that being part of a successful group can be crucial for survival, and that there could be natural selection at the group level as well as at the individual level.

At the other end of the spectrum, evolutionary biologist George Williams suggested in the 1960s that selection occurs at the level of genes, now known as the selfish-gene concept.

Others think that because the microorganisms living in and on an individual can play a big role in their success, there is selection for individuals plus their microbiome – together creating what they call the hologenome.

These ideas have been the subject of fierce debate. Some have dismissed the notion of group selection entirely or have claimed it is so weak that it is inconsequential. But many biologists now think that natural selection can act simultaneously at several different levels: in other words, multilevel selection.

"We think about these things all the time as humans, whether or not we're calling it multilevel selection," says Philson. For instance, people are more likely to succeed as part of a successful team or company, he says.

MARIA JANICKI/ALAMY

**Yellow-bellied marmots live in colonies with a single dominant male**

There is already a lot of evidence for multilevel selection from evolutionary experiments done in labs, says Philson. But in such research, animals are typically kept in controlled conditions with no predators. "In order to really understand what is under selection, studying them in the wild is so valuable," he says.

**62 years**

**How long a key study of marmot behaviour has been running**

To do this, Philson and his colleagues took advantage of a long-running study of yellow-bellied marmots (*Marmota flaviventer*) that began in 1962.

These ground squirrels live in groups with 10 to 20 members. The researchers analysed 20 years of data on the interactions between 700 individuals, who were part of 172 groups over this time.

They looked at individual characteristics such as how many other members of a group each individual interacted with. Philson and his team also examined group characteristics, such as how many connections between individuals there were in each group. They then worked out how these traits affected an individual's chances of surviving – that is, the strength of selection for each trait.

For marmots, being part of a group is important because other group members help spot predators. Better connected groups are less likely to break apart, says Philson, so being part of one boosts an individual's chance of survival.

But interacting with lots of other group members seems to be costly and reduces survival, the researchers found. So there is selection for more social groups, but against more social individuals (bioRxiv, doi.org/nq8b).

The analysis also takes account of the fact that individuals are affected by the group they are in, and that there is feedback between the group and individual levels, says Philson. "One of the reasons this is the first study that looks at this in the wild is because you need a lot of data."

## Social success

"It is very exciting to see these results in a wild system," says Vincent Formica at Swarthmore College in Pennsylvania. "This [study] demonstrates, in a very elegant way, that position in and structure of social networks are important traits with fitness consequences that cascade across levels of biological organisation."

"I think their claim that this is one of the first good studies of multilevel selection in nature is correct," says William Ratcliff at the Georgia Institute of Technology. In some fields of biology, such as microbiology, the idea of multilevel selection is now widely accepted, he says. In others, such as animal behaviour, it remains controversial.

Some of those who are sceptical about multilevel selection have no doubt that there is selection of plants and animals at the individual level, says Ratcliff. "Yet all multicellular organisms consist of groups of cells, with natural selection acting on heritable group-level traits. This is, in fact, group selection."

Philson says that what his study can't show is whether any of the selective pressures on marmots leads to evolutionary change. This would require demonstrating genetic changes, he says, which is extremely difficult with traits related to social behaviour. ▮

Physics

# A gas that breaks the laws of physics

Moving heat from a cold area to a warm one isn't normally allowed, but a thin gas may do the trick

Karmela Padavic-Callaghan

HEAT always spontaneously flows from a hotter place to a colder one – so says the second law of thermodynamics. But within an extremely sparse gas, the opposite may be possible, with heat flowing from cold to hot. This finding could reveal cracks in a foundational law of physics.

"Given the second law [of thermodynamics] has been known for 150 years, you would imagine that if a counterexample exists, then it must be in some exotic system, like in string theory," says Yu Qiao at the University of California, San Diego. But he has found one by modelling the behaviour of a few particles zipping around in a box.

Qiao and his colleagues simulated a box filled with a very dilute gas – it is so thin that the particles will never interact with each other, but they can bounce off the sides of the box. The top and bottom of the box absorb heat when any particles touch them. Typically, a box filled with gas like this would show all the hallmarks of the second law of thermodynamics – if any part of it started off hotter than the rest, heat would flow to colder parts of the box until the whole thing evened out at the same temperature. This equilibrium state would also be the one with most entropy, or the least order.

**"Claims of breaking the second law of thermodynamics often lead to fanciful proposals"**

Qiao says he expected that the gas would never reach equilibrium because the particles couldn't collide with each other, but something more unusual seemed to happen: even when the bottom of the box was colder than the top, particles would still move upwards and carry heat from the colder part of the box to the warmer one. Qiao says this is because warmer particles always move more quickly than colder ones, so they are more likely to overcome gravity's pull and make it to the top of the box and lose their heat there, while the already slow and cold ones will, in the absence of collisions, stay at the bottom. The work will be published in *Physical Review E*.

It may be that instead of breaking a tenet of the second law of thermodynamics, this odd system reveals that under some conditions, the law's two parts – the direction of heat transfer and the increase of entropy – may not always go hand in hand.

"It's just under these very special conditions without particle-particle interaction, [entropy] is maximised in such a way that allows cold-to-hot heat transfer," says Qiao.

Milivoje Kostic at Northern Illinois University says claims of breaking the second law of thermodynamics are common and often lead to fanciful proposals like perpetual motion machines. But in more than 150 years, no one has managed to provide unambiguous experimental evidence for having broken the law, he says.

"This is a nice effect of fundamental interest, but perhaps not of much practical relevance," says Emil Roduner at the University of Stuttgart in Germany.

Still, Qiao is confident in his idea and has experimental tests in mind. He says that working on this mathematical investigation made him realise that one of his own experiments from 15 years ago may fit the bill: in that set-up, small amounts of liquid were pushed into tiny cavities within a porous solid and consequently couldn't touch each other. He says that some of the data from that old experiment had struck him as odd but unexplainable at the time and now he is seeing it with new eyes.

Ultimately, Qiao wants to design a useful device based on his new concept, such as one that could generate electricity based on the energetically cheap cold-to-hot heat transfer. "But because the second law is so fundamental, this [new work] is something that I would also happily retire with," he says. ▮

Materials

## 3D printing with light and sound waves

**A RAPID form of 3D printing that uses sound and light could one day produce copies of human organs made from a person's own cells, allowing for a range of drug tests.**

**Traditional 3D printers build from a hard base, layer by layer. This is time-consuming and risks damage to printed objects when they are removed from the printing bed. David Collins at the University of Melbourne and his colleagues have a different approach, which they call "dynamic interface printing".**

**The new printer is essentially a hollow, pressurised tube that is lowered into a bath of resin. Air pressure maintains an interface between the open end of the tube and the resin, which cures and hardens when exposed to light. By projecting slices of an object onto this interface one at a time, the printer can build up a 3D structure.**

**Speakers are used to vibrate the interface, creating waves that speed up the curing process. This means the printer is much faster than comparable resin 3D printers, laying down 0.7 millimetres of structure per second compared with a prior record of 0.14 millimetres per second, says Collins.**

TESSA VAN DER RIET

The 3D printer can produce delicate shapes by suspending them in resin

**So far, the researchers have printed objects up to 3 centimetres in diameter and 7 centimetres long, with a resolution of 15 micrometres. "That allows us to print structures on the scale of a single cell," says Collins (*Nature*, doi.org/nq25).**

**One of the first applications of the 3D printer the team envisages is to take tissue samples from a patient and print functional, custom tissue models. This could one day mean multiple functional 3D kidneys for a patient could be printed quickly and tested with an array of drugs to see which ones work best, says Collins.** ▮

James Woodford

Archaeology

# Clues to the invention of writing

Some symbols from an early Mesopotamian script can be traced back to cylinder-shaped seals that were rolled over clay to record transactions, reports **Michael Marshall**

FRANCK RAUX/2001 GRANDPALAISRMN (MUSÉE DU LOUVRE)

**A Mesopotamian cylinder seal and its design imprinted onto clay**

THE world's oldest known writing system may have had its origins in the imagery on decorated cylinders used to denote ownership or record transactions. Some of the symbols on these cylinder seals correspond to those used in proto-cuneiform, a form of proto-writing used in Mesopotamia.

The finding indicates that the invention of writing in Mesopotamia was a decentralised process, in which many people across a wide area contributed to the set of symbols used.

"There's been this longstanding reconstruction of how writing appeared in Mesopotamia, which

**"Perhaps administrators and traders scattered over the region played a role in the invention of writing"**

is arguably the earliest invention of writing in the world," says Silvia Ferrara at the University of Bologna in Italy. "We're retracing the trajectory in a way that's more, I would say, colourful."

The oldest known true writing system is cuneiform, invented around 3200 BC in Mesopotamia. It was preceded by a simpler system called proto-cuneiform, which was in use from 3350 to 3000 BC.

Proto-writing like proto-cuneiform is distinguished by a lack of grammatical rules, which means it can't convey complex meanings, says Amy Richardson at the University of Reading in the UK, who wasn't involved in the research. For instance, proto-cuneiform can be used to label something as "seven bushels of wheat", but only true writing like cuneiform can say "seven bushels of wheat will be delivered to you".

The origins of proto-cuneiform have often been traced to clay tokens. These came in a variety of shapes, such as discs and spheres, and were often engraved with patterns. The tokens could be pressed into wet clay, creating a symbol. Some of the symbols on the tokens are similar to those found in proto-cuneiform.

There is some evidence for a role of tokens in the origin of proto-cuneiform, says Ferrara. "But you cannot explain all the signs."

Ferrara and her colleagues Kathryn Kelley and Mattia Cartolano, also at the University of Bologna, have instead explored another source of symbols: cylinder seals. These cylindrical objects have patterns and images embossed on them and leave a rectangular collection of symbols when rolled over sheets of wet clay. The symbols often referred to goods being transported or to administrators involved in transactions, says Cartolano.

## A decentralised origin

The team examined cylinder seals from a wide area of south-west Asia, including Mesopotamia, that dated to 4400 to 3400 BC. They found several symbols that corresponded to proto-cuneiform symbols (*Antiquity*, doi.org/nq2x).

"One of the clearest examples that we found is the use of the images of a fringed cloth and a vessel in a net," says Cartolano. These have well-understood meanings: they refer to the transport of goods. And they are found both on cylinder seals and proto-cuneiform tablets.

The idea that the symbols on cylinder seals led to some of the symbols in proto-cuneiform was previously suggested by Holly Pittman at the University of Pennsylvania in Philadelphia in a 1994 book chapter.

"I am gratified that, 30 years after I first proposed the fundamental role of seal imagery in the origins of proto-cuneiform script, that a new generation of scholars have taken up my idea and, with their expertise in cuneiform script, have put details to my argument," says Pittman. She adds that in the 1990s, her idea was dismissed "without serious consideration".

"I find it to be very convincing," says Richardson. "There does seem to be a really neat correlation in the particular examples that they're illustrating in this article." Her own research has found that cylinder seals were also used to record interactions between cities.

This doesn't mean that tokens didn't play a role. "I think there's still some strong arguments to make that those tokens really are part of the foundation of abstraction," says Richardson. In particular, they seem to have been important for the development of counting systems.

If proto-cuneiform really did arise in this hodgepodge way, drawn from tokens, cylinder seals and possibly other sources, it may tell us something about who was inventing it, says Ferrara. "There is evidence for making a claim that the invention of writing in Mesopotamia was, in fact, much more decentralised than we think," she says.

While powerful people in the major city of Uruk no doubt played a role, perhaps so did other administrators and tradespeople scattered over the region. "I think there's evidence for having a more widespread... and more distributed prompt to writing," says Ferrara.

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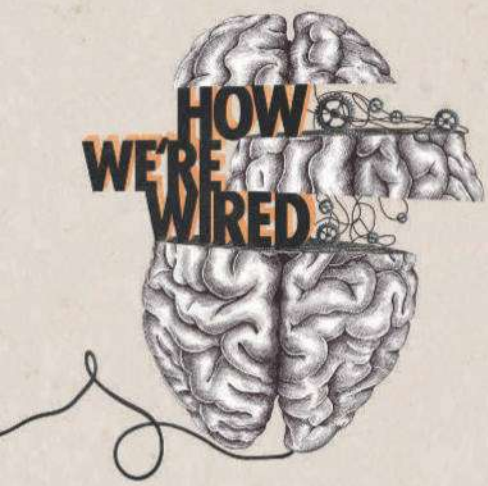


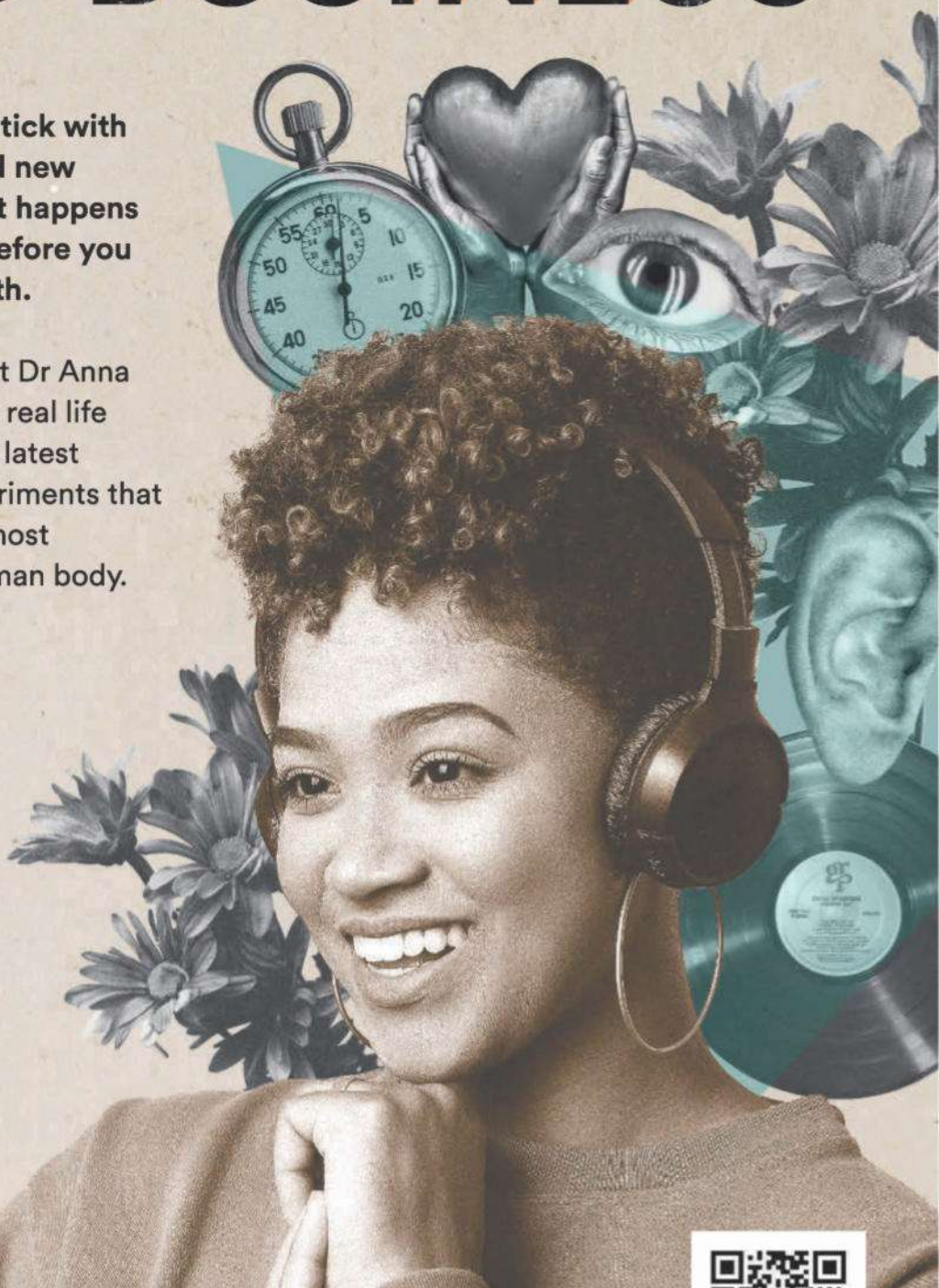

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Health

# Worldwide death toll from cancer is expected to nearly double by 2050

Grace Wade

THE number of cancer deaths globally is expected to nearly double by 2050, largely due to increases in low and middle-income countries.

Habtamu Bizuayehu at the University of Queensland in Australia and his team made the discovery by looking at recent figures for cases and death rates for 36 types of cancer in 185 countries from the Global Cancer Observatory database. They then projected future cases and deaths by applying these rates to the 2050 population predictions from the United Nations Development Programme.

They found that the number of cases worldwide is expected to grow by nearly 77 per cent between 2022 and 2050, which would mean that 35.3 million new cases will be logged in 2050 compared with the 20 million recorded in 2022. Global cancer deaths are also projected to rise by almost 90 per cent in this period, with 8.8 million more fatalities in 2050 compared with 2022, in which the disease killed 9.7 million people.

**35.3m**

**The number of new cancer cases expected worldwide in 2050**

The largest increases are expected in countries with low or middle rankings on the UN's Human Development Index, which is based on average life expectancy, education level and income per person. Cancer cases and deaths are, on average, predicted to nearly triple by 2050 in countries with a low score, such as Niger and Afghanistan. Meanwhile, nations with a very high score – such as Norway – are projected to see cases and deaths increase, on average, by more than 42 per cent and 56 per cent, respectively (*JAMA Network Open*, doi.org/nq6p).

This reinforces other evidence showing that cancer cases are trending upwards, says Andrew Chan at Massachusetts General Hospital in Boston, who wasn't involved with the study. Multiple factors are probably driving this, including people living longer, which raises the risk of cancer, he says. However, the work didn't account for the advent of new or more effective treatments.

Less-developed countries will probably see the greatest increases due to the "so-called Westernisation of populations", says Chan. "Some of the habits that we traditionally associate with higher risk of cancer, such as rising rates of obesity and poor diet, are becoming a trend in low and middle-income countries." ▮

STR/AFP VIA GETTY IMAGES

**Screening tests, which assess samples of cells, can help detect tumours**

Biology

## Vampire bats have rare ability to use protein as fuel

**EXPERIMENTS with vampire bats running on treadmills have revealed they have a highly unusual method of getting energy from protein, due to their specialised diet.**

**Most mammals get the bulk of their energy for movement from fats and stored sugars, but the three species of vampire bats subsist on a diet of blood drawn from their prey, which is rich in proteins but low in fats and sugars.**

**How their metabolism works is therefore unclear, as amino acids, which make up proteins, typically supply less than 10 per cent of animals' energy during exercise.**

**To learn more about their metabolism, Kenneth Welch and Giulia Rossi at the University of Toronto in Canada studied 24 adult common vampire bats (*Desmodus rotundus*) captured in Belize.**

**The bats were fed cows' blood containing amino acids with labelled carbon atoms, then placed on a treadmill in a small box. Unlike most bats, vampire bats have the ability to run at speed, which they use to track prey on the ground.**

**The bats' metabolic rate was measured by monitoring oxygen intake and carbon dioxide expiration while they ran on the treadmill at speeds of up to 30 metres per minute.**

**By analysing the carbon isotopes in the exhaled breath, the researchers found the bats were drawing energy from their recent meal rather than from stored fats or sugars (*Biology Letters*, doi.org/nq2p).**

**Obtaining most energy from amino acids is unusual in the animal kingdom, confined to blood-feeding insects, emperor penguins during long periods of fasting and hibernating bears.**

**"What's different here is that this seems to be what this animal is going to do all year round, every day when it feeds, and that it's making use of the protein in that blood meal that it ingested just minutes before," says Welch. "That's what really separates these animals from most of the rest of us."**

**"This animal is making use of the protein in blood that it ingested just minutes before"**

**While most animals can turn nutrients into sugars and fats and store them away, vampire bats have evolved a different strategy that leaves them far more susceptible to starvation – in fact, they are at risk of starvation after only 24 hours without feeding, says Welch.**

**To compensate for this, they have developed strong social bonds and will share meals with each other when one member of the group has failed to find food, regurgitating some of their own blood meal into another bat's mouth to sustain it.** ▮

**Matthew Sparkes**

Partner content paid for by Sanofi

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# People first

## *The **future** of treating autoimmune type 1 diabetes*

**Ahmed Moussa,**
**General Manager, Sanofi UKIE**

Type 1 diabetes is an autoimmune, complex, and lifelong condition – and it can happen to anyone at any age, even without a family history.[1] It can be a challenging condition with lifelong clinical, economic, and emotional unmet needs for patients and families. In the UK, there is a growing prevalence where approximately 400,000 people are living with the condition, including about 36,000 children 19 years and younger.[2,3]

I am encouraged and motivated to see people, companies and Governments striving towards creating innovative solutions that can help people with autoimmune type 1 diabetes (aT1D), to manage the condition better, allowing millions to live much longer than those who had the condition at the dawn of the Twentieth Century - we've come a long way since the discovery of insulin in 1921.

Nevertheless, we still know so little about aT1D. What triggers the condition is unclear.

It is known that aT1D is not caused by diet or lifestyle like type 2 diabetes, however, the causes of aT1D are still not completely understood. Researchers are exploring the genes and environmental triggers to understand if they play a part in causing the body's immune system to malfunction and start attacking the insulin-producing beta cells in the pancreas.

What we can be certain of, however, is Sanofi's commitment to helping the diabetes community receive the best care possible.

For more than a century, we have been at the vanguard of scientific research, delivering life changing medicines for people living with aT1D. Our long-term focus in this field has helped us understand how each person's experience of diabetes varies and that they will benefit from different health solutions at different stages in their lives.

However, at Sanofi, a century's worth of experience has taught us that if we are to truly improve the lives of those living with aT1D, and those at risk of a future diagnosis, we must look beyond managing this chronic and progressive autoimmune condition.

**Looking beyond management:** Right now, the goal must be to reduce as much of the burden of aT1D as possible, so that individuals live fuller, all-round healthier lives.

We at Sanofi believe people with aT1D can live fuller, healthier lives - if we, along with other stakeholders in the diabetes community think about care in a more holistic way, one that takes the human being and puts them at the centre.

Having spent over 15 years in the pharmaceutical industry, I believe this holistic approach can pay dividends.

*"The more we can understand and support individuals, considering their concerns, their challenges, their lives – the more we can deliver a bespoke, person-centred approach that will help reassure them they are not alone, and they are receiving the best care possible, for the best possible quality of life. In so doing, we can help reduce much of the anguish that comes with managing a chronic condition."*

**Prof. Partha Kar, NHS England National Specialty Advisor, Diabetes**

This thinking inspired our recent partnership with Beano and Breakthrough T1D UK, to raise awareness of aT1D. This campaign also aims to tackle the stigma associated with aT1D, which can significantly impact emotional well-being, self-esteem, and even clinical outcomes for people living with the condition.[4] The introduction of Rhymin' Reema, to the Bash Street Kids in a one-off comic strip aims to tackle the stigma and show that children with T1D can be just like anyone else. She provides a positive and relatable role model, demonstrating that T1D is manageable and doesn't have to limit anyone's potential or quality of life. I'm proud to say we shared this campaign with the world just a few days ago on World Diabetes Day 2024 (14th November).

Elsewhere, we are launching initiatives to support people with aT1D more holistically, like KiDS*, our initiative to foster a school environment that creates a better understanding of diabetes and supports children with diabetes through a range of resources.

*"It is exciting to see how technology has helped us take a person-centred approach and to see health bodies like NHS England embrace this. Earlier this year NHS England unveiled a new strategy that will see the roll out of Hybrid Closed Loops real time glucose monitoring technology for a majority of patients diagnosed with aT1D over the next five years. This is after the success of the universal roll out of CGM in this population."*

**Prof. Partha Kar, NHS England National Specialty Advisor, Diabetes**

Aimed at children (aged 6-14), parents, teachers, school doctors, policymakers, and Government officials, it is intended to tackle stigmatization and support children with aT1D to manage their condition at school.

For some, aT1D can feel lonely and isolating. Studies suggest people with aT1D can be more prone to depression.[5] We at Sanofi are determined to help people navigate their diabetes journey with confidence and optimism.

Our holistic approach is led by innovation that drives change for individuals. We know, for example, that technology can enhance diabetes medications, enabling physicians to generate better insights into the health of each individual person living with the condition and then provide support and solutions specifically targeted at them. This is why, Sanofi, through our partnership with DarioHealth*, use the latest technology to develop apps and wearables, to better connect people to their bodies and their doctors and partner with health authorities to make sure people have access to healthcare.

We are excited about the potential that Artificial Intelligence (AI) and technology can play in the future of holistic diabetes management, to deliver personalised advice and support. AI could help deliver real-time health and metabolic information, promote better self-management practises for individuals, and save time and money by reducing travel to in-person appointments.[6]

I am happy to say that there is so much more great progress being made towards reducing the burden through innovation, wider than Sanofi, for example, the scientific community is actively investigating islet cell transplantation and stem cell therapy, and more.[7,8]

### The next 100 years:

The innovation is exciting, it is clear that we are at an inflexion point when it comes to our approach to diabetes. A century ago, the manufacturing of insulin was a gamechanger for previous generations living with aT1D.

Sanofi believes our commitment to person centred care will help us deliver an equally transformative next hundred years.

**Initiatives not available in the United Kingdom.*


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# Views


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The dirty business of mining metals to fuel a cleaner future p36

**Culture**
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Comment

# Sense of an ending

Evidence that animals grieve is growing, but we should be wary of letting our biases cloud this topic, says philosopher **Susana Monsó**

RECENT years have seen a surge of findings that suggest we aren't the only animals to mourn the death of loved ones. Scientists have documented cases like that of the orca Tahlequah, seen carrying her dead calf for 17 days and over 1600 kilometres, or young gorilla Segasira, who attempted to suckle from his mother's corpse despite already having been weaned, in a futile attempt to ease his distress at her lack of response.

Although these heartbreaking stories feel relatable, we should be wary of assuming that all non-human mourning must make sense from our perspective.

Consider the following. If you live with a dog and you were to die suddenly with no one else around, your pet would probably eat you. I have shared this fact with many an audience and always get the same mix of shock and nervous giggling in response. There is something deeply unsettling about the idea that our dogs may take the first opportunity they get to dig into us. And yet, despite appearances, this behaviour may show us that they care deeply about us.

Dogs, like wolves, are scavengers in addition to hunters. When a wild dog feeds on a carcass, they usually start to eat from the torso, which is where the nutrient-rich organs are. Only 10 per cent of these cases involve bites to the corpse's face. In contrast, when dogs feed on a deceased human caregiver, almost three-quarters of cases involve bites on the face,

ELAINE KNOX

while in only 15 per cent of them are there wounds to the abdomen.

The face is the part of our bodies our canine friends pay the most attention to because it is key to understanding our emotions and communicating with us. Thus, if we were to lie dead in front of them, they would probably try to get a reaction from us by nudging our face with their snout. We wouldn't respond, and this would probably cause our dog frustration or stress. When dogs are stressed, they tend to lick things – a self-soothing behaviour that calms them. So they might start licking our face, nibbling on it, and at some point they would draw blood and, well, one thing would lead to another.

What is interesting is that a pet dog's fixation on the face suggests this behaviour is born out of love for their carer and anguish upon the lack of response from that person. Thus, it may well be an expression of grief.

The study of animal grief has gained traction in the past few years with the development of a scientific discipline devoted to it, known as comparative thanatology. Despite the growing interest in this, the phenomenon of dogs that feed on their owners hasn't been considered relevant. The lack of attention to this probably springs from an anthropocentric bias.

When researchers look for a capacity in animals, they tend to begin by searching for human-like versions of it. This is why comparative thanatologists have focused on cases like Segasira's. But if we only look for human-like reactions to death, we will get a distorted account of how other animals relate to it. Some species, like dogs, may grieve in ways that are alien to us, and others may not grieve, but still understand death, like a carnivore that has no reason to mourn the demise of prey but has had enough experience killing to comprehend the meaning of what they have caused.

Our own behaviour is the most logical and easy place from which to start the journey, but now this discipline is up and running we need to shed our anthropocentric shackles and open our minds to the many ways in which other living things may deal with mortality.

The study of grieving animals, and of their relationship with death more generally, may reveal more unexpected aspects of non-human psychology, but only if we are willing to see the world through their eyes. ▮

Susana Monsó is the author of *Playing Possum: How animals understand death*

Field notes from space-time

# Universal perspective

Particle physics is no longer seen as vital by the US establishment, so funding has fallen. But its ability to create a sense of awe is priceless, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an associate professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her most recent book is *The Disordered Cosmos: A journey into dark matter, spacetime, and dreams deferred*

## Chanda's week

**What I'm reading**
*Maybe not the wisest choice, but I'm working through Sinclair Lewis's novel* It Can't Happen Here*, about a US dictator.*

**What I'm watching**
*I just saw Mexican horror film* Belzebuth *and can't recommend it enough.*

**What I'm working on**
*I just finished a first draft of a women's and gender studies syllabus for a course on gender and science.*

This column appears monthly. Up next week: Graham Lawton

PHILOSOPHER Helen De Cruz, in her new book, *Wonderstruck: How wonder and awe shape the way we think*, explains that "wonder is a useful emotion, because it points to gaps in what you thought you knew". I read this line while also working my way through Annie Jacobsen's book *The Pentagon's Brain: An uncensored history of DARPA, America's top secret military research agency*. DARPA, which stands for Defense Advanced Research Projects Agency, has an annual budget of over $4 billion, comparatively almost 20 per cent of that allotted to NASA. While you may never have heard of DARPA, you have probably used one of the innovations it helped develop, such as the internet.

What does a defence agency have to do with the philosophy of wonder? Well, a perennial debate about science is how well it should be funded and for what reasons. Implicit to this is the question of what should motivate the activity of scientists. In another book, *The Territories of Science and Religion*, historian Peter Harrison argues that this debate comes down to what he calls "material usefulness". This is another way of saying that it is a matter of what value to society research is.

However, what counts as materially useful alters over time. Today, we find ourselves in social and political structures that emphasise research outcomes that improve health, create better energy technologies, lead to new economic opportunities or support military endeavours. Harrison notes that early in the European Enlightenment in the 17th century, material usefulness was still organised around the morality of Christian theology. Our concept of material value changes, and this affects what we see as worthwhile in science.

This isn't just a philosophical question for me. A few months ago, I wrote about the push to save the Chandra Observatory at NASA (24 August, p 20). Some people loved this piece. There were also critics, especially among my colleagues, who worry that saving this orbiting telescope would mean opportunities for future missions get curtailed. Since NASA's astrophysics budget has been kept relatively flat, it seems tough choices have to be made.

I don't like what this means. Suddenly, scientists are at each other's throats about whose work deserves funding, when in fact all of it does. Should it be X-ray or ultraviolet astrophysics that we emphasise in next-generation space observatories? Both! Why should we have to choose? Of course NASA's budget is never going to be infinite, but neither is it true that the US can't afford a few more instruments. I don't need to convince other scientists of this, of course, so much as those who hold the purse strings.

> **"We don't need to be thinking of novel ways to kill each other to make exciting new discoveries"**

That should be the people, but in the US it is actually members of Congress and whoever is president. What motivates them? As Jacobsen's history of DARPA shows, security concerns and the desire to win the next war are extremely motivating for elected officials. In the past, anxiety about the Soviet Union and the prospect of nuclear war saw DARPA plant early seeds for the development of long-range drone aircraft. After these debuted in the early days of US-led wars in Afghanistan and Iraq, drones became a staple of militaries around the world. The technology has since made its way into commercial uses like farming.

One theory of how science happens is that people are at their most creative and efficient when motivated by war or economic competition. Consider Jacobsen's opening anecdote, about the first hydrogen bomb test in the Marshall Islands. Japanese and Indigenous people were badly harmed by this, and the land devastated. The night before the test, Jacobsen writes that scientists were betting about whether the detonation would set Earth's atmosphere on fire, destroying all life here. Despite the risk, they did it anyway.

It was an unconscionable choice to me. But one reason particle physics received funding in the following decades was because political leaders believed it might help the US discover new weapons. So whether I like it or not, this is my intellectual ancestry. These days, the US establishment doesn't see particle physics and astronomy as so militarily significant, and our funding reflects this shift. Does that mean what we do isn't important?

I think De Cruz's latest book answers this question: our work creates a sense of wonder, and wonder matters. It helps us identify gaps in our knowledge that could lead to breakthroughs. We don't need to be thinking of novel ways to kill each other to make exciting new discoveries. We should be motivated by intellectually nourishing ourselves and the generations to come. I think DARPA's budget should go instead to those of us who help create a sense of awe about the universe. ▮

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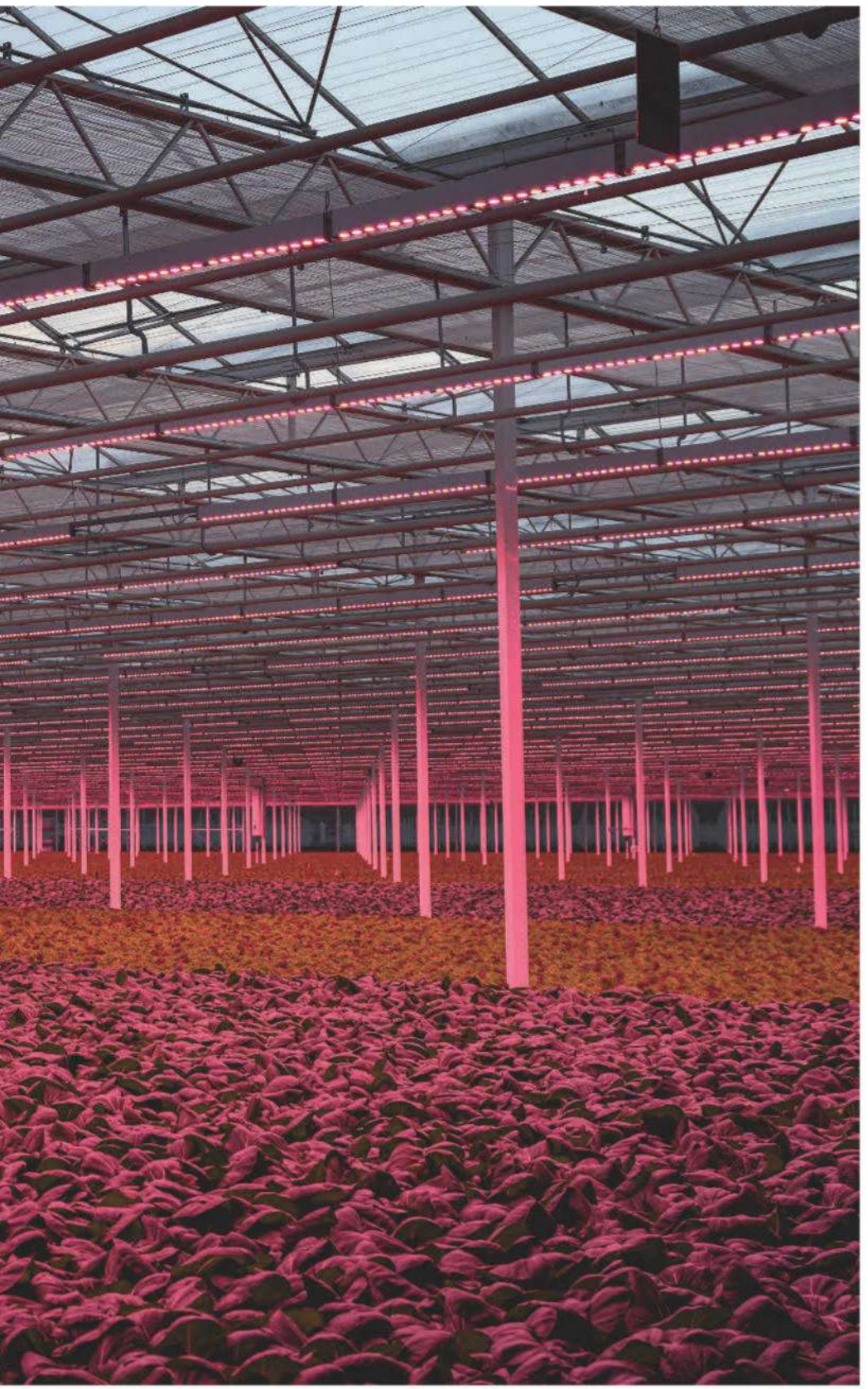

# Red shift

**Photographer** **Kadir van Lohuizen**

BATHED in a ghostly purple-red light, these floating lettuces are barely distinguishable from those grown outdoors, but require one-tenth as much land. The high-tech greenhouse where they live, in Maasbree in the Netherlands, is one possible remedy for a global food industry in crisis, facing a shortage of land due to climate change and conflict.

In his new book, *Food for Thought*, photographer Kadir van Lohuizen captures the food industry's struggle with these challenges, taking a whistlestop world tour of how the sausage, quite literally, gets made.

While high-tech solutions like the lettuce farm, left, and Plenty's vertical farm in Compton, California, shown below, promise to deliver us from food apocalypse, van Lohuizen doesn't shy away from the low-tech dystopia of much of the world's food production as it is.

He hopes that giving an insight into the size of the industry might make it easier to answer questions such as: how will it change in a rapidly warming climate, and which solutions are feasible? His *Food for Thought* exhibition, featuring video, photography and sound, is at the National Maritime Museum in Amsterdam until 5 January 2025.

**Alex Wilkins**

*For more on the global food crisis, see page 44*

## Editor's pick

### Boozy hornets may find drink is their downfall

**2 November, p 18**

*From Stephen Cadney, Manchester, UK*

**Sofia Quaglia's article on the oriental hornet's liking for alcohol could explain why the commonest trap in Portugal for the Asian hornet works so well. It may also enable an immediate and easy measure to protect bees if these predators become established elsewhere.**

**This trap uses an empty plastic 1 or 1.5-litre water bottle, with the top cut off, inverted and taped back on to form an entry tunnel. The bottle is then filled a third to half full with an equal mix of undiluted blackcurrant juice, white vinho verde (mildly sparkling, young wine) and a light blonde beer (like San Miguel). Apart from the occasional wasp, all we have caught over several years in Portugal are Asian hornets. A local beekeeper caught 600 over a long weekend by placing these traps by his 18 hives.**

### Insects hold answer to the fish farm feed dilemma

**26 October, p 16**

*From Butch Dalrymple Smith, La Ciotat, France*

The havoc wrought by feeding farmed fish with wild-caught fish could be eliminated if industrial-scale insect farming were used to provide the feed instead.

While convincing people to eat insects is an uphill struggle, it is relatively straightforward to get them to do so indirectly if they are "transformed" into fish first.

### Votes for and against a return to pure democracy

**Letters, 2 November**

*From Sam Edge, Ringwood, Hampshire, UK*

Roger Morgan worries that citizens' assemblies can become self-selecting due to large-scale refusal to participate, and hence polarised. The simple solution to this, hinted at in the original article, is to make participation compulsory in the same way that jury duty and, in some countries, voting are, allowing for rare exceptions due to personal circumstances. Failure to participate could result in criminal proceedings and risk a prison term and financial penalty.

Combine that with truly random selection from the whole citizenry – including children or those who are homeless or imprisoned – and you have a representative sample.

*From Derek Bolton, Sydney, Australia*

In your look at ways to create direct democracy by the people, for the people (5 October, p 32), Laura Spinney ascribes scientific and philosophical achievements of ancient Greece to such a system. However, science has also flourished under caliphs, tsars, queens, popes and emperors.

In addition, a problem with direct democracy is that most people have insufficient time and ability to take a holistic view. Do I want lower taxes? Yes. Do I want better public services? Yes. The principle of the parliamentary system is that you vote for someone you consider to have the skill and, by virtue of being paid, the time to take such a view.

### Shackleton's doomed ship makes an incredible sight

**2 November, p 24**

*From Gerald Legg, Hurstpierpoint, West Sussex, UK*

What an amazing image of Shackleton's ill-fated ship Endurance. The preservation is astonishing compared with that of Titanic. Endurance sits on the seabed at a depth of 3008 metres compared with Titanic at 3800, so both very deep and cold, but the former appears to be in much better order with few signs of steel decay. Is there any explanation as to why it looks so good?

### Millions of South Koreans handle home fermenting

**2 November, p 39**

*From Ben Strulo, Felixstowe, Suffolk, UK*

When it comes to fermented food, Isabelle Savary-Auzeloux recommends finding a trusted source and cautions against the do-it-yourself route. That will seem strange to people in South Korea and other countries where traditional fermented food is routinely made at home.

Like most home-cooking techniques, fermenting requires some care to be safe. However, I think the consensus among food scientists is that as long as normal food hygiene and reputable recipes are followed, then it isn't risky. Aspiring fermenters shouldn't be put off.

### We will get closer to the true nature of reality

**12 October, p 40**

*From Don Dennis, Isle of Gigha, Argyll and Bute, UK*

I see inherent self-contradiction in Daniele Oriti's statement that "we make reality". This is to claim to know reality. It is akin to saying that "there is no truth in words".

Science advances roughly in step with our ability to make measurement. We have had only a few centuries of scientific progress. Imagine what perspective we may have on the underlying nature of the universe if we were to survive in societally decent ways for another million years. I doubt that reality is capable of being fully understood, but our glimpses will become more compelling as we manage to make finer, increasingly groundbreaking measurements.

### Early claim of cannibalism on voyage led to backlash

**5 October, p 15**

*From Peter Clements, Adelaide, Australia*

Regarding cannibalism on the Franklin expedition to find the North-West Passage, 19th-century Scottish explorer John Rae reported signs of this, but was ostracised as a result, and never got proper recognition for his findings.

### Trying to explore sleep's twilight zone

**26 October, p 42**

*From William Lloyd, Sydney, Australia*

When it comes to trying to tap into sleep's twilight zone – those moments between being fully asleep and awake – I have been using a simple variation of the Thomas Edison metal ball system in the form of a book, which wakes me suddenly when it falls out of my hands while reading in bed. I am then wide awake and re-read the last paragraph, looking for the exact spot where I was overtaken by the "sleep-onset period".

However, I never seem to find it. The paragraph is initially crystal clear, but a moment later the book falls again, and the process repeats. After about four tries, I surrender myself into the eagerly awaiting arms of Morpheus.

### For the record

**Epstein-Barr virus was the first human cancer-causing virus to be identified (5 October, p 45)**

**Gravitational time dilation means that time flows more slowly when gravity is stronger, for example near a black hole (19 October, p 22)**

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# Mining the future

As we enter an "electro-digital age", **James Dinneen** welcomes a balanced briefing on the dilemma of mining the metals needed to ditch fossil fuels

Book

**Power Metal**

**Vince Beiser**

**Wildfire Books (UK, 20 November); Riverhead Books, (US, 19 November)**

JOHN MOORE/GETTY IMAGES

**Lithium for batteries being extracted in the Atacama desert, Chile**

THE lightweight smartphone in your pocket takes a heavy toll on the planet. If it is an iPhone, over 30 kilograms of ore had to be mined to harvest the metals within it, from the nickel and cobalt in its battery to the rare earths in its touch screen.

Even larger volumes of such "critical metals" play an essential role in most of the technologies needed to move on from fossil fuels. Wind turbines contain huge permanent magnets made with rare earths such as neodymium. The electricity they generate is carried on a power grid made of copper wires to charge electric vehicles with batteries made of dozens of kilograms of lithium.

As journalist Vince Beiser explains in *Power Metal: The race for the resources that will shape the future*, all that material poses a Faustian bargain as we enter what he calls the electro-digital age. He writes: "Our high-tech, carbon-free future depends on one of humanity's oldest and dirtiest endeavours: mining."

*Power Metal* is no exposé. But his exploration of this dilemma is a balanced and readable brief on one of the more contentious questions of the energy transition. Beiser tours a lithium mine in Chile, visits a metal recycling centre near his Vancouver home and shadows several e-waste scavengers in Lagos, Nigeria.

For the most part, his book synthesises examples from the large body of research on the metals transforming the world. Yet just laying out the facts is damning enough. Processing rare earths in Inner Mongolia poisoned lakes and people's lungs. Nickel smelters have stripped forests in Indonesia. Copper mines are a major user of fresh water in Chile.

Mining generates around 7 per cent of global greenhouse gas emissions – and rising. Most of this happens far from the rich countries consuming the metals.

The social and geopolitical consequences are as significant as the environmental ones. In the Democratic Republic of the Congo, cobalt mining is rife with forced labour and violence. Nickel mining funds Russia's war in Ukraine. The concentration of production and refining of many of these metals in China gives it leverage over the global economy.

**"Mining generates around 7 per cent of global greenhouse gas emissions – and rising"**

The news isn't all bad. Under growing scrutiny, the mining industry has started to clean up its act. A rare earth mine in Nevada now recycles its wastewater. Lithium producers are exploring water-saving tech to separate the metal from brine. Researchers are looking at ways to extract metals from leftovers at former mines or even harvest them by growing metal-accumulating plants.

Beiser also finds delightful ways to show why the metals are so important to us: "Rare earths are like vitamins, or spices, or yeast, or LSD: they are used in tiny amounts but have major effects."

But most mining inherently involves tearing up the planet, and the incredible demand means the consequences are sure to expand, potentially even to the ocean floor via deep-sea mining. In one projection he cites, by 2050 annual demand for copper will be greater than the total amount used between 1900 and 2021. Demand projections for other metals key to the energy transition are also astronomical.

None of this is terribly new. Similar points are often made by critics of efforts to use renewable energy and electric tech to end our dependence on fossil fuels. And, like many of these critics, Beiser's mantra that "everything has a cost" suggests a false equivalence between mining and fossil fuel extraction. Calculations by data scientist Hannah Ritchie at the Oxford Martin School, UK, for example, show that the volume of metals needed for any green transition is orders of magnitude smaller than the volume of fossil fuels extracted from Earth's crust.

What makes Beiser's book valuable, however, is that his aim isn't to stop a transition he views as necessary to tackle climate change. Instead, he asks how we might limit its damage: "We must reshape our relationship to energy and natural resources altogether."

Recycling can reduce demand, but it is an energy-intensive, often dirty process and can't be the whole answer. More effective is reuse, made easier by the "Right to Repair" movement. Best of all is to use less, especially if you can avoid buying a car heavy with metal, electric or not.

# When men say nothing

A new documentary is a fresh and personal look into what happens if men bottle up their emotions, finds **Elle Hunt**

Film

**Silent Men**

**Duncan Cowles**

**In select UK cinemas from 19 November; US release in 2025**

**SCOTTISH film-maker Duncan Cowles has always been rubbish at talking about his feelings. He was born into a family of stoic, "silent men" for whom love is something you only express in a birthday card. By his mid-twenties, keeping everything bottled up started to get to Cowles and seem more personal because of the reported crisis in men's mental health.**

**Men are consistently less likely than women to seek help or admit they are struggling, despite decades of public health messages and mainstream discussion. In the UK, suicide is the leading cause of death for men under 50. Cowles wants to break the silence and "open up" – but how?**

**In *Silent Men: The awkward art of expressing emotion*, his first feature-length documentary, Cowles seeks not only to understand this emotional block, but to push past it. Over six years, from the age of 26, he records fumbling attempts at intimacy in interviews with his parents, his friends and volunteers.**

**On one level, *Silent Men* is a fond, personal, often funny exploration of the difficulty of communicating honestly with the people who know you best. But it also tries to provide a public service by shining a spotlight on unspoken suffering, something recognised in a special mention at its premiere during Sheffield DocFest, UK, this June. The festival's jury was "impressed by the vulnerable approach to a sensitive subject".**

**A self-effacing everyman figure, Cowles makes the most of his tortured self-narration and awkwardness on screen, often to comedic effect. Whenever he feels his material is getting too heavy, he cuts to nature scenes – illustrating how easy it is to put off difficult conversations. Even interviewees challenge him about whether the documentary is just a distraction.**

**It is a credit to Cowles's skill as a film-maker that you find yourself rooting for him to find the courage to tell his parents how he feels. Yet these elements, though engaging, can't help but keep his investigation into the crisis of men's mental health somewhat surface level.**

**Though Cowles wonders whether his emotional blocks are a product of nature or nurture, his enquiry is limited to a quick chat with a clinical psychologist, who suggests that though there are some distinctions between male and female brains, men's emotional reticence is more meaningfully the product of culture.**

**The psychologist refers to a study that purportedly found babies given blue blankets weren't held for as long as those with pink blankets. It appears to show the perniciousness of gender stereotypes – but citation, and more examples, would have helped give heft to Cowles's point that men face particular challenges.**

***Silent Men* is most powerful when Cowles turns the camera on others to show the potential harms of withdrawing emotionally. We meet "John" from Newcastle, UK, so determined not to show weakness or ask for help that he didn't tell his wife about his spinal tumour. Cowles shows how the secret destroyed John's marriage and nearly killed him. John's final speech, warning men not to suffer in silence ("It'll snowball, and it'll kill you"), might register when other warnings failed.**

**Cowles also shows the impact of silent men on women. When he interviews his partner about her experience, it is clear that the wounds from early in their relationship are still raw. Cowles's mother, too, admits she has learned to be less emotionally demonstrative after years with his taciturn dad.**

**His self-experiment in *Silent Men* is Cowles's attempt to break their pattern. Though he doesn't quite get the on-screen catharsis he craves, the film is a worthy tribute to the importance of pursuing connection, no matter the obstacles.** ▮

Duncan Cowles, pictured, explores the crisis in men's mental health in his new documentary

DUNCAN COWLES/RELATIVE FILMS

Elle Hunt is a writer based in Norwich, UK

Need a listening ear? UK Samaritans: 116123 (samaritans.org); US 988 Suicide & Crisis Lifeline: 988 (988lifeline.org). Visit bit.ly/SuicideHelplines for other countries

## New Scientist *recommends*

**Karmela Padavic-Callaghan**
**Reporter**
**New York**

Robin Wall Kimmerer is a botanist and member of the Citizen Potawatomi Nation. She made her name as a thinker at the intersection of science, Indigenous knowledge and a deep love of nature.

**The Serviceberry: An economy of gifts and abundance** is a single essay I read over a few commutes. Her warm, inviting style feels like you are having a conversation as you pick serviceberries (pictured), which taste like a mix of blueberries, strawberries and almonds.

She outlines her idea of an economy built on gift-giving, reciprocity and relationships – a currency that could replace today's "cutthroat capitalism", she argues. While her standpoint is one of environmental concern and sadness for the effects of corporate greed, and she is stern and full of conviction, Kimmerer isn't didactic or condescending.

Her book offers a good dose of optimism and encouragement, which makes it a lovely read and a potentially transformative one.

MICHAEL MEIJER/GETTY IMAGES

# What binds art and science?

The US's biggest art event takes on science this year, promising to make Southern California a showcase for creative challenge, says **Christian House**

Exhibition

**PST ART: Art & science collide**

**Multi-venue, Southern California**

**Closes 16 February 2025**

FLORIAN VOGGENEDER/VOG.PHOTO

**Above: Indigenous artist Kite. Below: A liturgical fan from *Lumen: The art and science of light***

THE myth of the irreconcilably divided worlds of art and science is still alive. But it's nonsense, says Joan Weinstein, director of the Getty Foundation – the two have always been intertwined. She stresses this in her role as chief architect of *PST ART: Art & science collide*, a programme of over 70 exhibitions in Southern California over the next three months designed to interrogate the bonds between the two.

In 2017, Weinstein began talking to museum directors about the theme. "Everyone started sparking to the idea," she recalls. It was at a time when scepticism of science was on the rise – not long after the first election of Donald Trump.

The largest art event in the US, *PST Art* is supported by over $20 million from the Getty Foundation, distributed to institutions ranging from the Los Angeles County Museum of Art to small, regional galleries. Weinstein says the project's strengths are a "multiplicity of voices" and a breadth of themes, such as Indigenous knowledge, scientific futurism, environmental justice and climate change.

The festival is timely. From her office in the Getty Museum in Los Angeles, Weinstein points to a skyline bathed in a haze: "That is smog, that is pollution." Appropriately, at the Hammer Museum, an affiliate of the University of California, Los Angeles, the *Breath(e)* exhibition will address the lungs of our planet – oceans, forests and the atmosphere. Works include a botanical installation by Los Angeles-based guerrilla gardener Ron Finley and a sculpture by Garnett Puett, created in collaboration with bees.

Scientific progress has shaped Southern California's recent history, says Weinstein. The technology that came out of the region's aerospace industries and places like NASA's Jet Propulsion Laboratory (JPL) was adopted by Hollywood, she notes. Fittingly, the entertainment world is well represented in the project. For example, the Academy Museum of Motion Pictures is presenting *Cyberpunk: Envisioning possible futures through cinema,* which explores near-future scenarios.

FLORIAN MONHEIM/DOMMUSEUM HILDESHEIM

And at JPL, artists and staff come together for *Blended Worlds: Experiments in interplanetary imagination*. One data scientist at JPL believes the collaboration has reframed his work philosophically, according to Weinstein. "You could see how moved he was," she says.

Elsewhere, academic research drives *Growing and Knowing in the Gardens of China* at San Marino's Huntington Library, focusing on the gardens of China's cultural elite in the 17th century. And at the Getty Center, Los Angeles, visitors explore a medieval obsession in *Lumen: The art and science of light*.

At the Roy and Edna Disney CalArts Theatre (REDCAT) in downtown Los Angeles, curators look to the future in *All Watched Over By Machines of Loving Grace.* The artists are critical of artificial intelligence and their exhibition asks, what if algorithms were written by communities of colour and LGBTQ+ groups?

One of the show's performances involves Indigenous artist Kite and Mexico City-based collective Interspecifics, bringing together machine-learning technologies, sound, the body and Indigenous cosmologies.

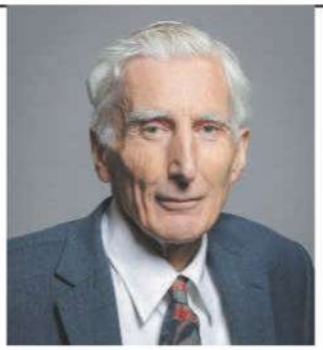
**"Weinstein says the project's strengths are a multiplicity of voices and a breadth of themes"**

With politically charged themes and claims of greenwashing and artwashing prevalent in the museum world, Weinstein is sensitive to conflicts of interest. Tech companies approached the foundation to collaborate, but were turned down. So, will the festival create arguments in this election year? "I hope so," she says. ▮

Christian House is a writer based in London

RSA

**From mapping the mysteries of black holes to shaping international science policy, Sir Martin Rees, Lord Rees of Ludlow, is a renowned British astrophysicist and cosmologist.**



First joining as an RSA Fellow forty years ago, Sir Martin is best known for his pioneering work in galaxy formation and the structure of the universe. Having served as the Astronomer Royal, President of the Royal Society and currently a member of the House of Lords, we asked Sir Martin to share why the RSA Fellowship remains close to his heart and continues to inspire him.

**Why are building connections important?**

Curious about the power of professional networking in the science world, we asked Sir Martin Rees for his view. He emphasised the importance of establishing new connections as being "very important at all levels." He stressed the incredible value of building new friendships through professional societies and thought-provoking events like RSA's lectures and gatherings.

**Championing diversity**

From Sir Martin's perspective, the RSA Fellowship can cater to a wide range of individuals: "The Fellowship is very varied. I can imagine it is especially valuable for retired academics who are living in the country", he explained. For Sir Martin, living in Cambridge gives him the advantage of constant academic interaction. He acknowledged how, for those "retired to some small town where there is no immediate contact with people in their field", the RSA's community provides an invaluable opportunity for engagement. He went on to highlight how those in more remote locations "benefit hugely from these networks locally like Zoom" or, in person.

The RSA provides an enriching space for individuals to share ideas, grow professionally, and make long-lasting positive impact. As Sir Martin's experience shows, the Fellowship truly embodies a diverse, supportive, and forward-thinking community that benefits people at all stages of their lives.

The RSA Fellowship is open to everyone over the age of 18, and we actively welcome new voices and perspectives. We believe in building a diverse and dynamic community, so if you're interested in joining, the application process is straightforward and accessible to all.

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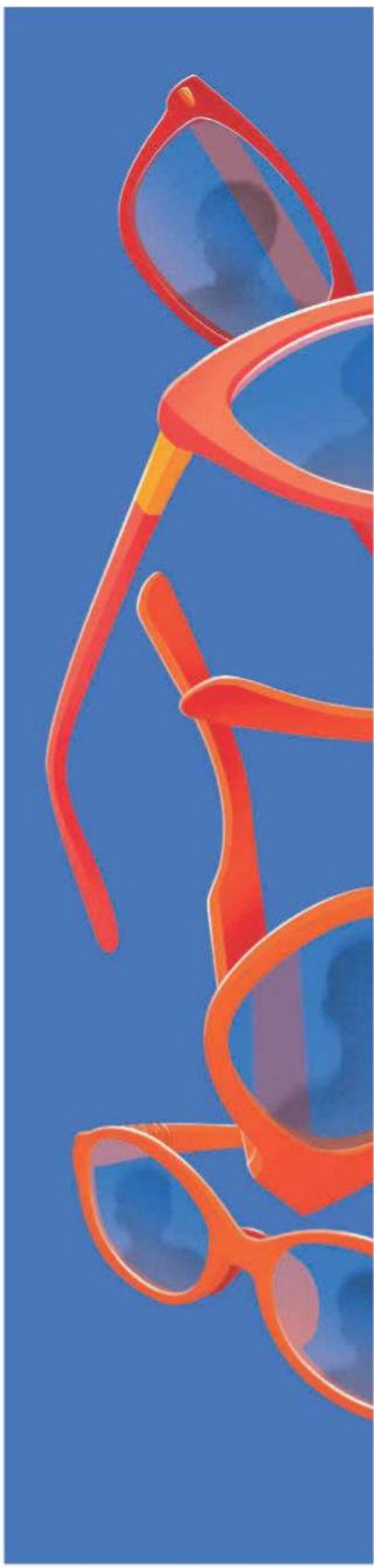
# THE MYOPIA EPIDEMIC

Near-sightedness is on the rise around the world, but is the end in sight for this surge in blurriness, asks **Graham Lawton**



NASH WEERASEKERA

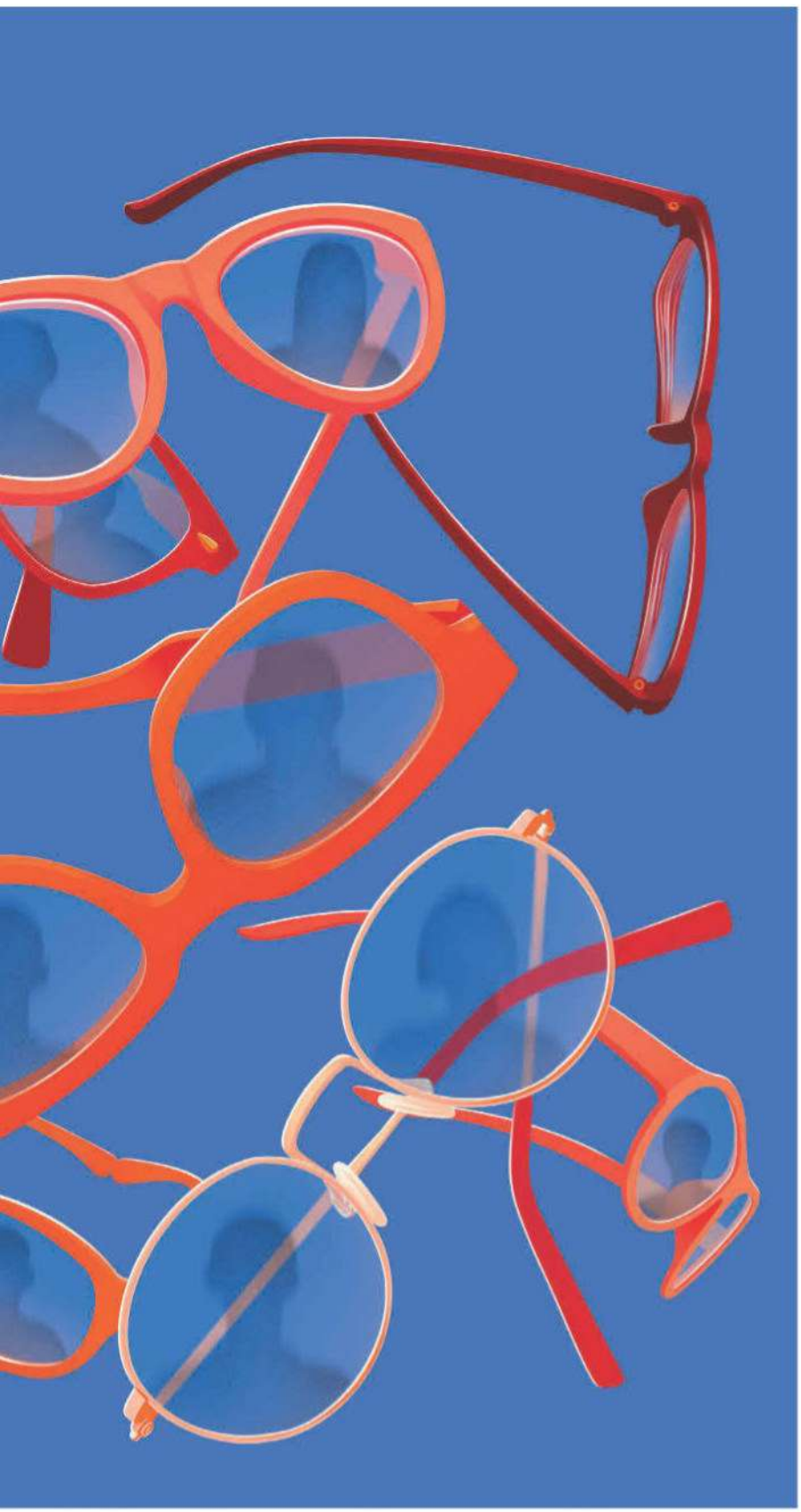
I VIVIDLY remember getting my first pair of glasses as a child. My mum is very near-sighted and dispatched me to the optician every year. My older sister was diagnosed at around the age of 8 and I prayed I wouldn't follow suit for fear of being made fun of, but by the time I was the same age, the world was becoming a blur. That year's visit to the optician confirmed it, and I have worn glasses or contact lenses ever since.

Back then, in the late 1970s, it was quite unusual to need glasses at such a young age. Not any more. Over the past 30 years, there has been a surge in near-sightedness, or myopia, especially among children. Today, around a third of 5 to 19-year-olds are myopic, up from a quarter in 1990. If that trend continues, the rate will be about 40 per cent by 2050 – or 740 million myopic young people.

That is more than an inconvenience. "Myopia is a disease," says K. Davina Frick at the Johns Hopkins School of Medicine in Maryland, who co-chaired a recent US National Academy of Sciences committee on the condition. "It has wide-reaching quality-of-life and economic implications," she says, not least the risk of going blind in severe cases. Increasingly, however, researchers think the epidemic can be slowed – or even reversed.

Most cases of myopia are axial, meaning the axis of the eyeball – the distance between the cornea at the front and the light-sensitive retina at the back – grows too long. This means that light entering the eye is focused in front of the retina, rather than on it, causing blurred vision. (Refractive myopia, which is less common, occurs when the eye's cornea or lens is abnormally curved, causing blurriness.)

Babies are generally born long-sighted, but become less so as their eyeballs grow. When



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the sweet spot of perfect focus is reached, around their first birthday, the eyeball stops growing, a process called emmetropisation. Or, at least, it is meant to. In some children, the stop signal doesn't arrive or is ignored, and the axis continues to elongate gradually. That growth speeds up and typically peaks between the ages of 8 and 16, according to Katherine Weise at the University of Alabama at Birmingham.

Exactly why emmetropisation fails in some people is unclear. But once the retina is pushed beyond the perfect focal point, vision worsens progressively. Ophthalmologists refer to this as the "myopia cliff", the point of no return – glasses, contact lenses and laser eye surgery, which permanently changes the shape of the cornea, can correct the blur but don't cure the underlying problem.

The lifetime cost of correcting myopic vision runs into thousands of pounds for each individual, but for around 10 per cent of people with axial myopia, there are added complications. Once their prescription goes beyond -5 dioptres – a measure of the strength of the lens needed to correct their vision – they are said to have high myopia.

That is potentially catastrophic, says Weise. "You don't get a new retina – it has to stretch to accommodate the growth of the eye and that's where you get some thinning at the edges." This increases the risk of four conditions that can lead to irreversible blindness: detached retina, myopic macular degeneration, glaucoma and severe cataracts.

## The great blurring

High myopia is more likely to develop if children fall off the cliff early. Myopia tends to progress by about half a dioptre a year in schoolchildren, according to Weise, so 10 years or more of abnormal and rapid eye lengthening can push them over the threshold. There is evidence that myopia is starting earlier, as soon as 3 years of age, according to Daphne Maurer at McMaster University in Hamilton, Canada. With estimates predicting that half of the world's population will be myopic by 2050, more people will spend more of their lives affected by this.

What is causing the global blurring isn't entirely clear, though there are clues. Although it is possible we are testing eyesight more regularly and therefore seeing more accurate rates of myopia, Weise says this would only explain a tiny percentage of the increase. ›

And though there is a genetic component – a child with one myopic parent is about twice as likely to become myopic as a child with none, while a child with two myopic parents is five times more likely – the increase is happening too quickly to be down to genetic change, says Don Mutti at Ohio State University. "So that makes us concentrate on environmental factors."

Various culprits have been proposed – poor diets, urbanisation, increased screen time – but the evidence for all of these is weak. For many years, "near work", any activity requiring close-up focus, was believed to be a cause of myopia. But "the evidence is just not there," says Mutti, adding that smartphones, books and TV aren't an important part of the problem.

The real villain seems to be too much time indoors. Spending time outside has long been known to be protective against developing myopia, for reasons that are still unknown, and "it is certainly the case that kids are outdoors less and indoors more than previous generations", says Mutti.

THE ASAHI SHIMBUN VIA GETTY IMAGES

"THIS IS A DISEASE WITH WIDE-REACHING QUALITY-OF-LIFE AND ECONOMIC IMPLICATIONS"

MICHAEL WHEATLEY/ALAMY

**Myopia among children is increasing the world over, but outdoor play can protect against it**

## Get outside

The power of increasing kids' time outdoors was demonstrated by a nationwide experiment in Taiwan. In 2001, 34.8 per cent of children there aged 6 to 12 were myopic; by 2010, that figure had risen to 49.1 per cent. Alarmed by those numbers and motivated by the belief that too much near work was behind the precipitous rise, the government made changes to the school curriculum that year, encouraging 2 hours a day of outdoor activity.

Though near work probably wasn't the cause of the children's myopia, the experiment worked: within four years, the rate of new cases in Taiwan dropped from a peak of 50 per cent of children aged 7 to 12 to 46.1 per cent. It is still going down, although it hasn't dropped back to where it was in the 1980s.

Another, more recent large-scale unintentional experiment also highlighted the importance of outdoor time: the covid-19 pandemic. Myopia rates rose dramatically in nations where children had to stay inside for long periods, according to a number of studies correlating lockdown policies and myopic progression.

The case for outdoor time as protective against developing the condition is supported by clinical trials and reviews – the highest quality evidence. Based on multiple studies, the recommended level is at least 1 hour a day, preferably 2, and being exposed to a light intensity of at least 5000 lux, says Mutti, which is about the intensity you get in natural shade on a sunny day. Indoor light is typically a tenth of this or less.

The need for time outdoors may also explain the apparent link between myopia and near work. "I don't think there's strong evidence that what kids are doing indoors is a specific source of the myopia problem," says Mutti. "It is the fact that they are indoors."

Problem solved? Not entirely. Ideally, children aged 3 and above should be getting 2 hours of daily outdoor exposure, says Mutti, but this isn't always possible. Moreover, being outdoors doesn't stop kids who have already gone over the myopia cliff from falling further. "It would be nice to have a better understanding of what exactly is good about time outdoors so we can enhance its effect," says Mutti, or replicate it indoors – prolonged exposure to the sun increases the risk of skin cancer, and outdoor light intensity can't be relied on to hit 5000 lux every day.

Even though light intensity seems to matter, this is only part of what is known as the "visual diet". The spectrum of light is also different indoors than it is outdoors, as is the range of near and far objects, requiring the eye to focus on different points, the light-dark contrast and the level of fine detail the eye needs to resolve. Any or all could be involved in developing myopia, according to many researchers.

"Luminance, this 5000 lux figure, seems to be somewhat key," says Rick Born at Harvard Medical School. "But there's a lot more research to be done in terms of dissecting what it is about the outdoors that's better. As we identify these features, we can start to

"WAYS TO TACKLE THE GLOBAL PROBLEM OF MYOPIA ARE FINALLY COMING INTO FOCUS"

bring the benefits of the outdoors into the indoors." That might mean changing indoor illumination in schools, for example, to better mimic natural light.

In the meantime, there are interventions that can slow down the elongation of the eyeball. One is eye drops containing a drug called atropine, which partially paralyses the muscles that change the aperture of the iris and reshape the lens while it is focusing on near objects. Atropine was first tested in the 1960s, on the basis that near work caused myopia, so limiting the eye's ability to focus might solve the problem. It works to some extent, though researchers now know that the original rationale was wrong and they haven't settled on a convincing alternative. "We don't have a full understanding of why atropine works," says Weise. The same goes for a similar drug called pirenzepine. Both, notably, come with unpleasant and common side effects, including blurred vision and light sensitivity.

The other treatment options include special glasses and contact lenses designed to blur peripheral vision. Researchers hypothesised that lenses fooling the peripheral vision into thinking it is myopic – called myopic defocus – would produce a stronger stop signal for growth of the eye and slow its elongation. "If you supply myopic defocus to more of the retina, you put the brakes on eye growth," says Mutti. Another option is orthokeratology, rigid contact lenses that are worn at night and change the shape of the cornea in a way that helps improve vision.

According to a recent review of all the published studies on controlling myopia, orthokeratology and atropine are the best available treatments, while others also work to some extent. But even the best therapies only reduce myopia by, at most, three-quarters of a dioptre before grinding to a halt.

"None of them work as much as we'd like them to. None of them prevent myopia," says Weise, nor do they treat the underlying elongation. "Treatment effects are best in the first year – why would that be?" says Mutti. "We need solid evidence of exactly why they're working."

There are also signs that the therapies may ultimately do no good, or even lead to harm, says Weise: once the treatment is stopped, the eyeball can enter a period of rapid, haphazard "rebound" elongation, which may produce worse vision in the long run than slow and steady growth. For example, in research published in 2023, a team led by Yong Li at the National University of Singapore retested the vision of people who had been treated with atropine 10 or 20 years previously. The researchers found no difference between these groups and those with untreated myopia. "Are we just delaying the inevitable?" asks Weise.

## Better treatments

All of which points to a great need for better treatments. To get those, we need to clearly understand the mechanisms behind myopia, including what the eye growth "stop" signal is. "If we could understand this process, how biochemical signals create that growth… any part of that would help us to have much more effective treatments," says Machelle Pardue at Emory University in Atlanta, Georgia.

One promising avenue is understanding the visual system's method of detecting contrasts between light and dark. Known as the ON-OFF pathway, it is mediated by specialised cells in the retina connected to the brain's visual cortex: bright light stimulates the ON pathway and darkness the OFF pathway.

"There's evidence that defects in the ON pathway lead to myopia," says Pardue. For example, people with a condition called complete congenital stationary night blindness, which is caused by genetic mutations in the ON pathway, tend to develop high myopia. So do mice in which the ON pathway is blocked.

Further evidence suggests that being indoors means getting insufficient bright light to stimulate the ON pathway and that firing up this pathway prompts the release of dopamine in the retina, which has been proposed as a possible stop signal for eye elongation. At the moment, research suggests that the ON-OFF pathway could offer a unifying theory of myopia and even a route to a permanent solution. "This is a theory at this point, but it deserves additional research," says Pardue.

In the meantime, new treatments are being rolled out, including what's known as repeated low-level red light (RLRL) therapy. In this, laser light with a wavelength of 650 nanometres and a luminance of 1600 lux is shone onto the retina for around 3 minutes, twice a day. It was developed to treat amblyopia, or lazy eye, but was inadvertently discovered to slow the progression of myopia – and in some cases send it into reverse.

In 2022, a team led by Mingguang He at Sun Yat-sen University in Guangzhou, China, published the results of a clinical trial of RLRL therapy, finding that it significantly slowed the progression of myopia. They also found, unexpectedly, that in around 40 per cent of the participants, the length of the eyeball shortened and vision improved. This sometimes happens spontaneously, but was much more common in the people who were treated – "a novel and important finding", according to the researchers. Other studies using this therapy have since had similar results.

"It looks like it works really well," says Weise, though there are signs of strong rebound growth when the treatment is stopped. But it hints that the spectral composition of light hitting the retina matters, she says. "I do think there is something to the chromaticity of light and how we might use it to fool the retina into not growing."

It may be too late for my eyes, but ways to tackle the global epidemic of myopia are finally coming into focus. "We are no longer fixing just the blur associated with near-sightedness," says Weise. "This is a treatable condition, and we'd like to figure out how to treat it." ▮

**Myopia requires lifelong vision correction for many activities**

LUIS ALVAREZ/GETTY IMAGES

Always consult your doctor before deciding on any medical treatment

Graham Lawton is a staff writer at *New Scientist*

ADOBE STOCK

# Recipe for disaster

As global temperatures rise, food supplies are becoming less secure. So how do we ensure there will be enough for a growing population, wonders **Michael Le Page**

YOU have probably already noticed that the price of many of the foods in your grocery basket has risen – a lot. In the UK, the cost of white potatoes is up 20 per cent in the past year, with carrots up 38 per cent and olive oil up 40 per cent. And while that means the expense of putting together a roast dinner is soaring, specialty items are suffering even bigger hikes – you will now pay nearly double for some bars of chocolate.

What is driving prices up is complex, but one of the biggest factors is climate change. In the short term, extreme weather caused by a warming climate has had devastating consequences for growers. In northern Europe, for instance, torrential rains in spring 2024 left fields too sodden to harvest vegetables or plant new crops. Meanwhile, a drought in Morocco, which typically exports a lot of vegetables to Europe, meant there wasn't enough water for irrigation. The result was soaring prices for potatoes and carrots.

As the average global temperature zooms past 1.5°C above pre-industrial levels in the coming years, heatwaves, droughts and extreme storms are going to become even more common and severe, causing greater disruption to food production. But current efforts to compensate for the impact of poor harvests – such as clearing forests to grow more crops – make many other problems worse, from biodiversity loss to increasing carbon dioxide levels. With such big impacts on so many foods already happening, have we underestimated how bad the effect will be? And what can we do about it if we have?

Every crop needs particular conditions to thrive – too hot or too cold, too wet or too dry, and yields will be lower. To understand how global warming will affect yields, climate scientists use computer models to work out how conditions might change in growing regions. Early versions of these models suggested yields could fall in areas near the equator, where crops are already near their heat tolerance limits, but rise in areas further north or south. In fact, a 2007 report by the Intergovernmental Panel on Climate Change (IPCC) concluded that, thanks in part to the fertilising effects of higher atmospheric $CO_2$ on plants, food production would rise overall until the increase in global temperature exceeded 3°C, after which it would begin to fall.

## Uncertain outlook

The forecast now, based on improved modelling, is less optimistic. The latest IPCC report, issued in 2022, warned that food security will be increasingly affected by global warming and the climate events associated with it, creating the "possibility for surprises".

Not only are newer climate models projecting much stronger effects, both positive and negative, but the latest crop models also suggest the impact on yields will be much greater too, says Jonas Jägermeyr, a climate scientist at NASA's Goddard Institute for Space Studies in New York. A recent modelling study by his team projected that wheat yields could rise by up to 18 per cent by 2100 in a high emissions scenario, while maize yields could fall by 24 per cent. These figures aren't forecasts, but rather give us an idea of what would happen if farmers keep doing what they are doing now.

But current models also have some serious limitations. "Realistic projections probably would be a little bit less optimistic," says Jägermeyr, noting that climate models aren't good at projecting extreme events and that crop models tend to underestimate impact.

Another major limitation is that these models don't consider the risk of pests and diseases. As the planet warms and becomes more humid, some pathogens will spread to areas where they haven't been able to survive before.

"Where the crops are doing better, their pests and diseases will tend to do better as well," says Dan Bebber at the University of Exeter in the UK. "We need to be prepared for invasions of new pests and pathogens that we haven't seen before." For example, one factor behind soaring olive oil prices is a devastating bacterium called *Xylella fastidiosa*, which, after being found in Puglia, Italy, in 2013, went on to kill more than a third of the region's olive trees within a decade. Warmer temperatures are helping it spread in Europe.

Another issue with the model studies, according to David Lobell at Stanford University in California, is that they often focus on staples such as wheat and maize, rather than also considering specialised crops like cocoa and coffee. Because these grow in fewer places, their supply has proven more vulnerable to extreme weather. Most of the world's cocoa comes from just four countries in West Africa, where recent harvests have been devastated by drought, heavy rainfall and a disease called swollen shoot virus. Prices of chocolate have risen precipitously in the past few years in response. "We didn't really have a good sense of what was going to happen there," says Lobell of specialty crops.

So far, it is also proving harder for farmers to adapt to the changing climate than we thought – which is deeply worrying, given that the changes now are small compared with those expected in the next few decades. "Earlier studies did show the potential for negative impacts, but they were quite optimistic on how easy it would be to avoid those impacts by just making shifts in the types of varieties that are being grown," says Lobell. "It's not going to get any easier if the changes are bigger."

And yet, overall food production has been rising. Lobell's studies suggest that wheat and maize yields would have been a few per cent higher by now in a world without climate change, but we have kept ahead of the climate curve in part by increasing adoption of fertilisers and mechanisation by farmers. However, that means we are having to use ›

more energy to grow the same amount of food, says Bebber. "Once you control for our agricultural technology, the impact of climate change is already with us."

The other reason for rising food production is that the global area used for growing crops is expanding rapidly. This often involves turning forests into farmland, which is catastrophic for biodiversity. Clearing trees also puts a lot more $CO_2$ into the atmosphere, adding to farming's already large carbon footprint – about a third of our greenhouse emissions come from agriculture.

## A vicious cycle

Alarmingly, we seem to be at the start of a vicious cycle: global warming is making it harder to grow food, so farming is becoming more emissions-intensive to keep up, leading to yet more warming. The rising temperature will also amplify other threats to world food production, including ocean acidification, groundwater depletion and soil loss, intensifying that cycle further – for instance, hotter temperatures mean farmers need to use more groundwater for irrigation.

"The risk that we face is not a risk just to the food system. The risk we face is to the entire climate system, to the entire ecosystems of the world," says Lobell. "Problems with food quickly spread to land-use change, biodiversity loss, climate emissions. That's the scenario that we definitely want to avoid. But in some ways, we're in that scenario right now."

The biggest short-term concern isn't that those on a high income will go hungry, but that we will continue to damage the planet trying to keep supermarkets stocked. To be clear, as the 2022 IPCC reports warns, simultaneous extreme weather events in several parts of the world could lead to major food shocks, but we do have buffers in the form of food reserves and the repurposing of crops currently used for biofuel and meat production for human consumption.

For those on low incomes, things are very different. Estimates say more than 700 million people – 9 per cent of the global population – faced hunger in 2023, 150 million more than in 2019. That number is expected to increase with global warming.

"It's not just about producing more food," says Jägermeyr, it is about producing food where it is needed, at a price people can afford.

However, if we pass some potential climate tipping points, maintaining the global food supply for everyone will become even harder – and we may be approaching one fast. Vast areas of the Brazilian rainforest are being burned down to become cattle ranches. Close to 18 per cent of the Amazon has been deforested, says Carlos Nobre at the University of São Paulo in Brazil, making the region hotter and drier and increasing the risk that the Amazon will die.

"Studies indicate that if we reach 20 to 25 per cent deforestation, and global warming exceeds 2°C, we are going to reach the [Amazon rainforest] tipping point," says Nobre, making it more difficult to grow food. That will have significant negative consequences for all of us – Brazil produces around 10 per cent of the world's food by weight, including half of global soya bean exports and a third of beef exports.

So what do we need to do to keep producing enough to eat, without causing even more problems?

"The short answer is everything," says Lobell. No single solution is a magic bullet – averting the coming food crisis will take a myriad of innovative and scalable responses.

One big answer is eating less meat. A huge proportion of the food we grow, especially maize and soya, is fed to animals rather than eaten directly by us. "If we use land more efficiently and feed humans rather than livestock, then all the problems go away," says Bebber.

## How you can help solve the food crisis

**EAT MORE ADVENTUROUSLY**
Growing a wider range of crops would make our food system more resilient to weather extremes, pests and diseases. But it is difficult for farmers to switch to crops for which there is little demand. So try some foods you may not have sampled before, such as breadfruit, and if you like them, keep on buying them.

**THINK TWICE BEFORE YOU BUY ORGANIC**
Organic food is marketed as environmentally friendly, but on average yields are lower. This means we would need a lot more farmland if everyone ate organic, accelerating deforestation and the loss of biodiversity as well as increasing greenhouse emissions related to land clearance.

**EMBRACE GM FOOD**
To save the rainforests, we need to produce more food on less land. Genetic modification is one of the best tools for achieving this. Take bananas, which have one of the lowest carbon footprints of any food, even when you factor in shipping. The popular Cavendish variety is being hard hit by the spread of a fungal disease, but a resistant variety has been created by gene editing. Its adoption, however, is being slowed by the opposition to genetically modified crops.

**FAVOUR LOW-EMISSION FOODS**
Producing a kilogram of mutton or cheese results in less than half the greenhouse gas emissions of 1 kg of beef, while 1 kg of pork and chicken results in a 10th of those emissions. So simply picking one kind of animal-derived product over another can make a big difference. Fruits and vegetables usually have much smaller carbon footprints than any animal product, so eating more of them is better and healthier, too.

**DON'T WORRY TOO MUCH ABOUT FOOD MILES**
Buying local is a long way from being the most important thing when it comes to the sustainability of what you eat. Locally raised beef can have a carbon footprint around 100 times as large as bananas shipped thousands of miles. Focus on what you eat rather than where your food comes from.

JIM WEST/ALAMY

**WASTE NOT, WANT NOT**
An estimated 60 per cent of food waste happens in households, so we all have a part to play in reducing this – which would be a win-win for us and the planet. There are lots of ways to reduce waste, but the biggest, of course, is to avoid buying food you are unlikely to eat before it spoils.

CLAUDIUS THIRIET/BIOSPHOTO/ALAMY

**Drought and wildfires are both on the rise, with negative impacts on crop yields**

Unfortunately, the opposite is happening. Although global beef consumption is down from around 11 kilograms per person per year in the 1970s to just over 9 kg today, population growth has meant that overall beef production has nearly doubled over this time. The global production of dairy and all meats has been rising steadily for decades, with no sign of any change in that trend – as incomes rise around the world, people eat more meat on average. One way to tackle this is to introduce taxes on meat that reflect the environmental damage its production causes. But few voters want that and, so far, no country has tried it.

We can also do more with the food we have. According to a 2024 United Nations report, a fifth of the food that reached shops, restaurants and consumers in 2022 went to waste. Producing that wasted food generated 8 per cent of global greenhouse gas emissions, while gases produced by food rotting in landfills also has a warming effect. Only a few countries are making progress on this: the UK, Europe's largest waster of food but also a signatory to the UN 2015 voluntary food waste reduction goal, is among them. Between 2007 and 2021, the country saw an 18 per cent reduction in food waste, and new legislation requiring businesses to separate food waste from other streams will come into effect from March 2025, showing that change is possible.

Modifying our behaviours can undoubtedly mitigate the damage (see "How you can help solve the food crisis", left), but there are other tools, too. Work to make crops more heat, drought and pest resistant is already under way. Scientists are also trying to design crops capable of making their own nitrogen fertiliser. Legume plants such as peas and beans host bacteria in their roots that convert nitrogen in the air into chemicals that plants can use, but researchers have so far been unable to induce this process in other crops. However, if achieved this would dramatically reduce greenhouse gas emissions caused by the manufacture and use of fertiliser, plus make food cheaper.

Other researchers are working on photosynthesis, the process by which plants harness sunlight to create the energy they need to grow. Photosynthesis is surprisingly inefficient – only about 0.3 per cent of the energy in the light hitting a field of wheat ends up in the harvested grain. In 2022, a team led by Stephen Long at the University of Illinois Urbana-Champaign reported yields up to a third higher in soya beans modified to make them photosynthesise more efficiently. This claim has been disputed, but further trials are ongoing. If it works, the impact would be huge: selective breeding has improved the yields of soya beans and maize by only about 1 to 2 per cent each year, and these are among the highest gains for any crop. But by combining multiple ways of boosting photosynthesis, Long says it might be possible to increase yields by more than 50 per cent.

Technology can also improve farming practices: precision agriculture and robotics can, for example, apply nitrogen fertilisers more efficiently, reducing greenhouse gas emissions and the pollution from agrochemicals washed off land into rivers and streams.

Then there is taking the field out of farming. Growing plants in controlled conditions, such as in greenhouses, can protect them from extreme weather and make yields more reliable, but the energy cost to keep conditions controlled can be high. Another not entirely new approach is to grow food in vats – the meat substitute Quorn, for example, is produced this way from a soil fungus. However, the challenges of growing fungal, plant or animal cells in vats means the products can be prohibitively expensive. Those cells also still have to be fed, and because the nutrients used presently come from crops grown in fields, the environmental footprint of the final product isn't necessarily that much better than the products they replace.

**"Governments should pour money into securing food production, but they are doing the opposite"**

But what if we could make nutrients directly using energy and plentiful raw materials, rather than relying on photosynthesis to do the job? Earlier this year, a Finnish company called Solar Foods became the first to produce food commercially this way, using electricity to split water into oxygen and hydrogen, then feeding the latter to bacteria that use it as their main food source. The final product is a yellow protein-rich powder called Solein that can be used as an ingredient in a variety of fare. Snack bars containing Solein are already on sale in Singapore.

Compared with producing the same amount of plant proteins, the company claims producing Solein results in a fifth less $CO_2$ emitted, while requiring a 20th of the land and a 100th of the water. Questions remain whether this can be scaled up and whether people will buy it, but this kind of approach could have a big impact even if it is used only for animal feed.

We do have what it takes to make our food system more productive and resilient and less damaging to the environment. However, at a time when governments should be pouring more money into such efforts, they are actually spending less, says Lobell. "The combination of less innovation and more climate change is a very scary one," he says. "I think we can do a lot on both of those. But it's not going to happen overnight." ▮

Michael Le Page is a senior reporter at *New Scientist*

# Life on Mars

You might have heard about plans to establish a self-sustaining city on Mars. But have we really thought it through, ask **Kelly** and **Zach Weinersmith**

EARTH isn't doing so great. Thanks to human-induced climate change, the seas are warming and rising, while the land – in many places – is alternately choked in drought or inundated with floods. As for us humans, we are engaged in warfare on multiple continents, far-right movements are ascendant across the world and, as of last month, "dude wipes" are available with a pumpkin spice scent in the United States.

Meanwhile, the escape hatch to space is creaking open. Elon Musk's company SpaceX has a growing fleet of cheap, reusable rockets. In October, the booster stage for its mega-rocket, Starship, was caught in the grip of a skyscraper-high tower as it descended back to Earth. It was an impressive feat. But Musk's goal with these vehicles is even more audacious: to start a self-sustaining million-person city on Mars in the next 30 years.

Has anyone really thought this through? Well, yes, as it happens, albeit not Musk. We are a wife-and-husband research team – a biologist

STEVE NELSON

and cartoonist, respectively – and we have spent four years looking into how humans will become space settlers for our latest book, *A City on Mars*. We set out to write the essential guide to a glorious off-world future. What we learned, however, made us space settlement sceptics.

Here's the thing: Mars sucks. When you dig into what life would really look like on the Red Planet, in terms of the squishy details of human existence, it becomes hard to avoid an inconvenient conclusion – that moving to Mars to escape Earth would be like moving to a toxic waste dump because your neighbours aren't mowing their lawn often enough.

To rewind for a moment, we are space geeks. We love rocket launches and zero-gravity antics. We also hate being pessimistic, especially about an endeavour that so many of our fellow space enthusiasts think embodies the best of human nature. Unfortunately, the data led us in another direction.

Let's start with Mars as a destination. It certainly has its qualities: relative proximity to Earth, plentiful water, a day-length similar to our own, the chemical elements needed to support human life and temperatures that swing from a not-so-bad-by-space-standards -153°C (-243°F) to a positively comfortable 20°C (68°F) at certain locations. Plus, as the SpaceX website notes, perhaps in a nod to humanity's track record on climate change: "It is a little cold, but we can warm it up."

With all that said, Mars will remain worse than Earth even if the direst predictions of the consequences of climate change come to fruition. Take the air, for starters. The Martian atmosphere is mostly carbon dioxide, which, while popular among plants, is toxic to humans if breathed exclusively. To put it bluntly, if you step outside on Mars, you die.

Cosmic radiation is another problem. Thanks to Earth's dense atmosphere and the strong magnetic fields that surround it, the radiation criss-crossing its way through space is mostly screened out before reaching the delicate inhabitants on the surface. On Mars, which has no planet-wide magnetosphere and an atmosphere that is only 1 per cent as dense as Earth's, most of this radiation will make it to the surface.

Cosmic radiation is different to the radiation we typically experience on Earth, and the truth is that we have no idea how bad it is for us. Even astronauts living on space stations orbiting our planet are largely protected within Earth's magnetic field, which means we have very little relevant data on the effects of this radiation on humans, or on the other life we have sent into space. But a reasonable assumption held by almost everyone who has studied cosmic radiation is that constant exposure to elevated doses increases the risk of cancer.

All of which has knock-on effects for the question of where, or in what, we would live on Mars. Forget those illustrations of gleaming glass domes under which happy dinner-party guests drink wine and count the stars. That glass would let the radiation through. What we need is thick shielding. Indeed, most suspect ›

we will set up home inside long caves carved out by ancient lava flows, or else build shelters using onsite materials. That is, we will bury ourselves in Martian dirt.

Alas, this dirt, technically called regolith, is truly horrendous stuff. It may look like dust or sand, but without the gentle wear from wind and running water, regolith tends to be jagged and sharp. Breathing it repeatedly may cause scarring of the lungs similar to that seen in silicosis, a condition caused by breathing in silica dust from sources such as stonecutting or construction, leading to breathing problems and even death.

## Toxic dust

Regolith also happens to be laced with nasty chemicals called perchlorates. At high doses, these cause thyroid problems by competing with the iodine ions your body needs to produce certain hormones. This probably isn't good, especially for developing fetuses and children. Experiments conducted on Earth have found that plants grown in soil containing perchlorates incorporate them into their tissues, which means that any water or regolith from Mars will have to be detoxified before use.

Optimistic space-settlement enthusiasts say that perchlorates can be turned into oxygen. But we lean towards a less optimistic take. The thing is, when people talk about space settlement, they are often weirdly generous to conditions they would never accept on Earth. Imagine you are planning to have kids and are looking to buy a homestead, for instance. How do you feel about a real estate agent saying: "It's a great location, but I should mention the surface contains high levels of chemicals that are dangerous for children. And those chemicals can get taken up by edible plants, so if I were you, I'd convert those perchlorates to oxygen before you put in the veggie patch."

Speaking of food, we still have a lot to learn about how to grow enough of it in space. A typical journey to Mars takes more than six months, and settlers would have no choice but to stay for at least a year at a time to ensure the two planets are close enough to each other for the return journey. We will need to be self-sufficient, and growing food on site will require not only agricultural facilities, but excellent recycling systems too, as part of something scientists call closed ecological systems. One thing worth knowing about closed ecological systems is that humans aren't very good at living in them.

The most famous habitat of this type is Biosphere 2, a facility in the Arizona desert that ran a two-year experiment in the 1990s to see if eight people could survive sealed off from the outside environment. The only external inputs were sunlight and power from the local grid. Things went OK. Nobody died. But they were certainly hungry. The crew did physical labour eight to 10 hours a day, five and a half days a week, and the women lost 10 per cent of their body weight while the men lost 18 per cent. Also, at one point the carbon dioxide levels in Biosphere 2 started to soar, causing the Biospherians intense headaches and malaise.

Few experiments of that kind have been done since, and none on the same scale. In China's Lunar PALACE (Permanent Astrobase Life-support Artificial Closed Ecosystem), the setting of a 105-day experiment in 2014, there weren't enough plants in the facility to soak up the carbon dioxide exhaled by the three men living there. Levels fluctuated wildly, which isn't an ideal description of the behaviour of a toxic gas in your living space. However, when two of the men were replaced with women, the carbon dioxide levels stabilised at a low level and air quality improved. Among various lessons that might be drawn here, the one screaming at us is that more data is needed before we try to scale from a handful of people to the million Musk would like to land on Mars.

Lunar PALACE did succeed in other areas. For example, they were able to recycle 100 per cent of their water. Water recycling in space is something we know about, as fluids like urine, sweat and exhaled breath are collected and recycled on the US side of the International Space Station. This recycling is why astronauts refer to water as "yesterday's coffee".

The Lunar PALACE also grew 78 per cent of the participants' food by mass, and made good use of a protein source often proposed for space settlements: insects. What's not to like? They reproduce quickly, don't take up a lot of space, eat food scraps, are high in protein and you never name one Wilbur and fall in love with it. Proposed protein sources include crickets, silkworms, mealworms, hawkmoths, drugstore beetles, termites and flies.

In Lunar PALACE they used mealworms, which after a bit of seasoning were actually rated quite favourably by the crew. However, data of this sort can't always be trusted – participants in experiments like this are

"Would-be space settlers are weirdly generous towards conditions they would never accept on Earth"

SIMONAS ŠILEIKA/ALAMY

BUDDY MAYS/GETTY IMAGES

**The Biosphere 2 research facility in Oracle, Arizona**

often hoping that they will be picked by their respective government to become actual astronauts, so it is possible they were just trying to highlight what exceedingly good sports they are.

By contrast, the Biospherians weren't good sports – and the disagreements highlight some of the social and psychological challenges that a Mars colony would present. Tensions between crew members became so high that two crew members actually spat on a third. This was in a 12,000-square-metre facility, which is likely to be quite roomy compared with an early space outpost.

Between the carbon dioxide headaches, caloric deprivation and drive-by spittings, it is no surprise that some Biospherians reached out to mental health professionals. Unfortunately for Martian settlers, the vast distance between Earth and Mars means communication delays of between 4 and 24 minutes each way. So, while the inhabitants of Biosphere-2 could have real-time calls with family, friends and mental health specialists to help them get through their ordeal, on Mars you would be on your own.

## Gravity shortfall

And let's not forget the physical health issues settlers will face, which could be significant even when inside an underground bunker, protected from cosmic radiation and regolith. Astronauts in stations orbiting Earth are in constant freefall, effectively experiencing zero gravity. Despite hours of exercise most days, astronauts on the International Space Station lose 1 per cent of the bone density in their hips per month. Muscles experience similar degradation. Low gravity also appears to contribute to deteriorating vision, for reasons that aren't entirely clear, but which may have to do with the extra pressure on your brain and eyes when gravity isn't around to drag the fluids down.

While we know freefall is predictably disastrous for the human physique, we don't know the long-term effects of Martian gravity, which is about 40 per cent of Earth's. Maybe that will be enough to stave off bone, muscle and vision loss. Or maybe some combination of 40 per cent gravity alongside extra exercise and medications will do the trick. But after a long day of subsistence farming, dodging coordinated saliva strikes from crewmates and tucking into a lunch of mealworm tacos washed down with recycled urine, who really wants to jump on the exercise bike? Besides, what if 40 per cent gravity is bad for the human body, and no amount of exercise can make up for the gravity shortfall?

More concerning for the would-be settler is the fact that all the human data we have comes from adults who were in space for a year and a half at a time or less. A self-sustaining human settlement needs to be able to make more humans. That means conception, pregnancy, birth and developing into a mature human ready to repeat the above process. We know almost nothing about whether any of this can be done off-world. As far as we know, no human has ever had sex in space, let alone become pregnant. The research on reproduction in non-human animals in space has been scant, and it has been done mostly on space stations – which, as you now know, experience less radiation and gravity than you would get on Mars.

The biological research needed to adequately assess how dangerous pregnancy, labour and child development will be on Mars will take years to acquire, which Musk's plans for settling Mars don't seem to take into account. In our experience of this discussion with settlement enthusiasts, Musk isn't alone in this oversight. For example, we have had people argue with us that women give birth on Earth in dangerous situations and without medical interventions all the time, with the implication that it would be fine on Mars. Setting aside that many of those women die from lack of care, "We already fail to provide sufficient maternal care to all the women on Earth" isn't a great justification for doing the same on other planets.

Now, at this point, you are almost certainly thinking that we would politely but firmly decline any invitation to Mars. You would be wrong. Well, kind of. Because although we wouldn't go personally, we do want to see humanity settle the Red Planet.

The task for those of us who grew up watching too much *Star Trek* and *Doctor Who*, and who sometimes look up on a clear night and say to ourselves "ah, to hell with realism", is to figure out the path forwards.

It is a slow one, for sure. It sits on a mountain of hard-to-get data about human minds and bodies in an environment we didn't evolve for. It also involves sensible plans for how to deal with space law, international relations and societal organisation in a scenario where breathable air is rationed, something we address at length in our book. But as space tech advances and the needed experiments become more plausible, the question of how to responsibly expand beyond this planet becomes an important one.

To be clear, we don't think humanity will be saved by leaving Earth. Solving our problems here, now, is more important than a short-term rush elsewhere. Even so, we do believe that there should be no tension between those who want to go to space for humanity and those who want to focus on Earth for humanity. If we fail to deal with terrestrial problems, such as global warming and the threat of nuclear war, there will be no second chance. But when, one day, there is a city on Mars, it will be a product not only of great technology but also, we hope, great wisdom. ▮

Kelly Weinersmith is a biologist at Rice University in Houston, Texas. Zach Weinersmith is a cartoonist. They are the authors of *Soonish* and *A City on Mars*, which won the 2024 Royal Society Trivedi Science Book Prize

# The back pages


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## Stargazing at home

# Moonstruck

The moon's glare can frustrate astronomers, but **Leah Crane** has learned to love the jagged, cratered details of the lunar surface

Leah Crane is a features editor at *New Scientist* based in Chicago. You can reach her at launchpad@newscientist.com


OBSERVATIONAL astronomers hate the moon. This might be surprising to some of you – after all, the moon is gorgeous, it's the closest astronomical object we can observe and the dominant feature of the night sky on Earth. But that very spotlight is the problem: when the moon is out, its glare can hide nearly everything else. When you are looking for tiny details or deep-sky objects, that is a problem.

Even in just the next couple of months, there are two meteor showers that will each happen within a few days of the full moon, rendering them practically invisible. If you live in a bright city like I do and there is also a full moon? Forget about seeing just about anything else in the sky.

But as tempting as it is, I won't spend this entire column hating on the moon. After all, no matter how many times you have looked at it, there is always more to see.

You might think the best time to observe the moon is during its full phase, when its entire face is lit by sunlight, but that isn't quite right. See, the surface of the moon doesn't vary all that much in colour, so looking at it when it is fully bathed in light is a bit like looking down on a desert scene at high noon. You can see a few variations, but the full drama of the landscape is best seen when the sun is shining on the moon from an angle, so the moon isn't full and the relief of the landscape is brought out by the shadows.

The best place to look if you want to see those details is the terminator – the line between light and shadow. That's the inside curve of a crescent moon or right in the middle of a half-moon, the spot where the sunrise or sunset is happening. At that point, you can see long shadows cast by boulders over the lunar mare, bright spots where the light hits the edge of a crater just right and jagged ridges running through smooth plains.

NAGELESTOCK.COM/ALAMY

All of these features let us bear witness to the 4.5-billion-year history of our solar system, a history whose signs have been largely washed away on Earth by plate tectonics, running water and life. For every crater on the moon, there should be more than one on our own planet that has probably disappeared by now.

If you want to get really into the details of the lunar surface, I recommend trying to draw it. Not the whole moon, just as small a section as you can manage with whatever form of magnification you have. Colour in the darkest areas first, then move up a shade and draw the shapes of the next-darkest spots. Don't try to draw a portrait of the moon, just try to get the shapes right, and the shades of grey with respect to one another.

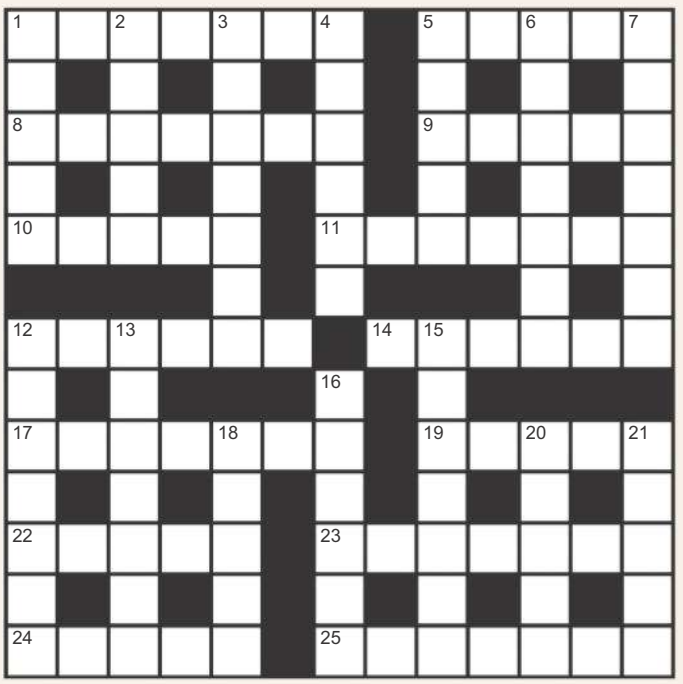
You will find that the lunar surface has surprising complexity. I am extremely bad at drawing and somehow I have drawn a picture or two of parts of the moon that, in my opinion, were actually good. So don't let a lack of artistic aptitude stop you! Give it a go, and maybe email me what you draw? ▮

*Share your stargazing successes with us on X and Instagram @newscientist using the hashtag #NewScientistStargazing*

**These articles are posted each week at newscientist.com/maker**

**Next week**
Mathematics of life

## Quick crossword #171 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

**ACROSS**

**1** Y (7)
**5** Not long (5)
**8** Sea snail (7)
**9** U, in set theory (5)
**10** T (5)
**11** Lip-like (7)
**12** Vacuum cleaner tradename (6)
**14** Measure of intelligence, supposedly (2,4)
**17** Cactus of Mexico and the southern US (7)
**19** Use a mouse button (5)
**22** Correctly adjusted (5)
**23** J.J. ___, US naturalist and artist (7)
**24** Climbing lizard (5)
**25** Tile (7)

**DOWN**

**1** Microorganism used in baking (5)
**2** Microsoft platform launched in 2017 (5)
**3** Archaeological period (4,3)
**4** Swiss health food (6)
**5** Firecracker (5)
**6** Add oxygen to (7)
**7** Least large (7)
**12** # (7)
**13** Living (7)
**15** Machine-readable data tags (2,5)
**16** Co (6)
**18** Relating to sound transmission (5)
**20** Permeate (5)
**21** Country of the Maasai Mara (5)

**Our crosswords are now solvable online**
newscientist.com/crosswords

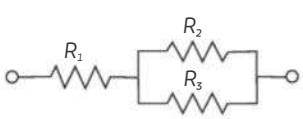
## Quick quiz #278
*set by Bethan Ackerley*

**1** Which of the following materials did Alfred Nobel not discover or develop: trinitrotoluene, ballistite or gelignite?
**2** What name is given to the multicellular adhesive structures found only in the tentacles of ctenophores?
**3** How many Space Shuttle orbiters were completed and made it to space during the 30-year programme?
**4** Physicist Wolfgang Rindler is credited with coining which term in black hole studies?
**5** What is the most abundant metal in Earth's crust?

*Answers on page 55*

## BrainTwister
*set by Phil Lloyd*
### #46 OhmWork

**When electrical resistors are connected in series, the total resistance is the sum of the individual resistances. When they are connected in parallel, the total resistance is found by taking the reciprocal of the resistance of each resistor, adding them together, and taking the reciprocal of the result. This circuit, using three 1-ohm resistors, has a resistance of 3/2 ohms:**




$$R_{total} = R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3}}$$

$$= 1 + \frac{1}{\frac{1}{1} + \frac{1}{1}} = 1 + \frac{1}{2} = \frac{3}{2}$$

**There are three more circuits using three 1-ohm resistors. What are their resistances?**

**A circuit uses 10 1-ohm resistors – three in series, then seven in parallel. What is its resistance? (It is an approximation to a well-known constant.)**

**Can you find a way to produce this value using only nine 1-ohm resistors? Hint: In this circuit, pairs of resistors in series occur four times, so there are effectively four 2-ohm resistors and one 1-ohm.**

*Solution next week*

## Question of scale

**Could there be a universe larger than ours, such that ours is a subatomic particle by its standards? And is it possible that, within the particles we know of, there are smaller universes?**

***Nick Canning***
*Coleraine, County Londonderry, UK*
You seem to have an image of multiple universes stacked within each other like Russian dolls, but with the possibility of the number of such dolls being infinite. This isn't how our universe works.

Our observable universe, a sphere of radius about 46.5 billion light years (enlarged from the expected 13.9 billion light years due to the continual expansion during the time since the big bang) is, under the current standard cosmological model, part of an infinite, flat universe. So, our observable universe is then only a minute fraction of the universe.

But to call it a subatomic particle is misleading. That suggests the laws of physics applicable would be those of subatomic particles and that is definitely not the case. The universe on these scales is essentially dominated by classical mechanical behaviour.

**"In such a big universe, subatomic particles would be completely deterministic little balls bouncing around"**

Are the actual subatomic particles, which are governed by the laws of quantum mechanics, themselves harbouring smaller universes? No, not of a form similar to our observable large-scale universe.

The geometry of the universe is not that of a fractal, which would be self-similar at all scales. There is an absolute scale delimiting large from small set by Planck's constant, h. The wave-particle nature of bodies is captured by de Broglie's relation: wavelength = h ÷ momentum. This sets the scale at which wave mechanics becomes more important than classical particle mechanics in the physical description of nature and separates the small from the large.

***Danny Kermode***
*Vernon, British Columbia, Canada*
No. At very small scales, quantum mechanics rules. The uncertainty principle says that we can't know both the speed and position of a particle with complete accuracy. At a human scale, we can't directly observe this phenomenon, but it defines the mechanics of subatomic particles. At scales smaller than that, individual objects and causal mechanics wouldn't exist.

That rules out a tiny universe. What about a universe where our universe occupies the space of just one particle? Life requires chemistry, and there can be no chemistry without quantum mechanics. In such a large universe, subatomic particles would be completely deterministic little balls bouncing around. There could be no life.

So the answer is obviously no. Or is it? Quantum theory isn't truth, it is a theory. In science, the only truths are direct empirical observations. The mathematics that we associate with observations and the predictions that we make from the mathematics are abstracted from those observations. We can never be 100 per cent certain that the next observation won't prove our analyses to be false.

We can attempt to apply our theories to universes on a scale that we can't directly observe, but we cannot claim that anything we say about them is "true" or "false". Quantum theory provides compelling evidence that the tiny and huge universes can't exist, but it doesn't say that they are impossible. That which isn't impossible is, from a purely semantic point of view, possible.

NICK UPTON/ALAMY

How does this jackdaw know how to build a nest – and does it really need such a large twig?

## This week's new questions

**Nesting knowledge** **How do birds know how to build nests?**
***Mike Vandeman,*** *San Ramon, California, US*

**Further dimensions** **Our eyes receive a two-dimensional image but our brains build a three-dimensional one. Could two three-dimensional images create a four-dimensional one, ad infinitum?** ***Hillary Shaw,*** *Newport, Shropshire, UK*

## Play on

**Presumably music is an essential part of human evolution or it wouldn't be there, but why?**

***Ros Groves***
*Watford, Hertfordshire, UK*
The evolution of music is an elusive yet tantalising subject as, unlike skeletons, sounds don't leave fossilised remains. The oldest known musical instrument is a 40,000-year-old flute made from bird bone, which predates the earliest known examples of written language by thousands of years, suggesting that music may have preceded language.

Fast rhythmic clapping and banging of sticks along with high-pitched howling could have been used by primitive communities in a form of "war rehearsal", symbolising readiness for an imminent attack by a rival group. Conversely, slow drumming and low-pitched murmurings could have been a signal for safety and sleep. Different pitch combinations could have marked apart one community from another so that each community had its own personal "tune" by which they identified themselves.

As farming communities grew and language developed, music became an art form in itself, not only to represent and recreate different emotions as is the case today, but also to inspire cooperation and hierarchy.

Turn-taking, characteristic of much music, may well have

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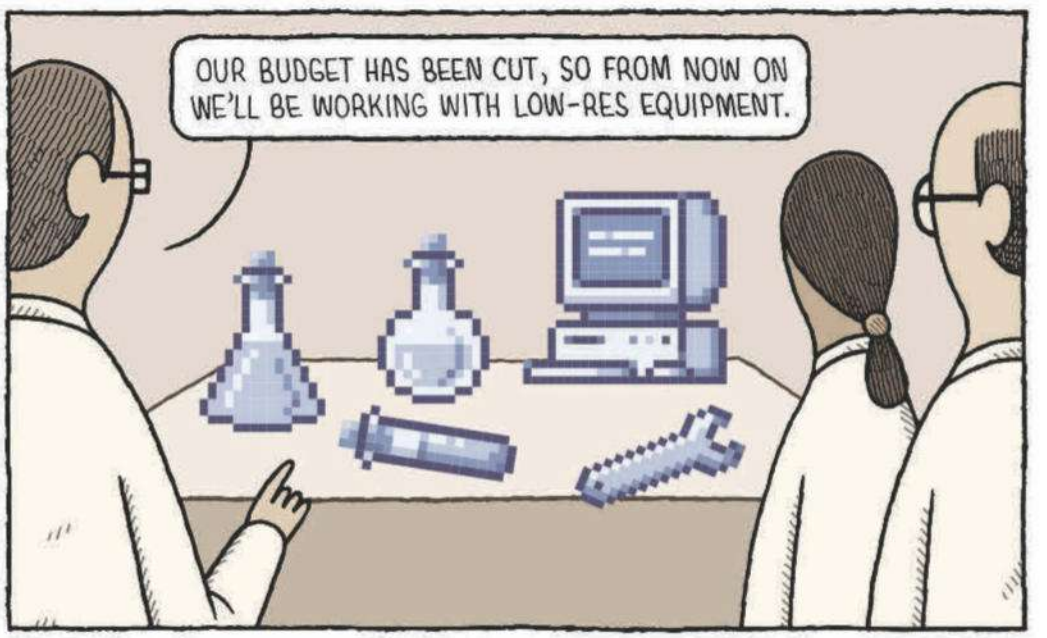
**Tom Gauld**
*for New Scientist*




reflected the division of labour within the group, reinforcing the need to know when to be passive and when to be active. Indeed, music was available to and practised by all, with no emphasis on virtuosity, but merely as a means for communities to simply enjoy themselves and to bond.

***Garry Trethewey***
*Arkaroola, South Australia*
This is an interesting idea that has been mooted in various forums, including this magazine. But it is a big jump going from something being there to it being essential.

There is a notion that appears in various guises that because some property or quality exists in a living organism, then it must be functional, or necessary, or even "perfectly adapted".

My hair has the property that it can be cut into various hairdos and dyed various colours, but I doubt that is an essential part of evolution. The ability or inability to smell asparagus in urine or to curl one's tongue can hardly be an essential part of evolution.

**"The ability of many people to do maths, to pollute our planet or to ski is obviously not an essential part of human evolution"**

The ability of many people to do maths, to pollute our planet or to ski is obviously not an essential part of human evolution.

I submit that all these things are adventitious side effects – some property exists that allows these things, but they weren't necessary in our evolution. Some might actually be dysfunctional, like cancer or appendicitis. They exist, but not in such abundance that the species is wiped out.

## Cosy spot

**Why do cats like to sit on newspapers and magazines? (continued)**

***Steph Györy***
*Via email*
Based on the observation of our two cats, they don't like to sit on newspapers and magazines per se, they like to sit on anything novel that appears in the house. Because your newspapers and magazines presumably come and go frequently, this is why your cat likes sitting on them.

***Virginia Lowe***
*Ormond, Victoria, Australia*
Any self-respecting cat will abhor a cat-shaped hole in the universe, especially if a beloved human is poring over it. It is almost always the very paragraph or sudoku you were engrossed in (but it can be a computer keyboard, too; size rules out mobile phones).

***Richard Hoptroff***
*London, UK*
I interpret their behaviour as them assuming they are supposed to sit there. I put circuitous stepping stones across our lawn and they immediately followed that trail, too. I have no explanation as to why, if you have several piles of paper on the floor, they sit on the most important one.

## Answers

### Quick quiz #278 *Answers*

**1** Trinitrotoluene
**2** Colloblasts
**3** Five
**4** Event horizon
**5** Aluminium

### Cryptic crossword #148 *Answers*

**ACROSS 1** Pedometer, **6** Jaw, **8** Station, **9** Gamer, **10** Dwelt, **11** Extinct, **12** Codons, **14** Indigo, **18** Finesse, **20** Tusks, **22** Reair, **23** Vulpine, **24** Yak, **25** Pargasite

**DOWN 1** Postdoc, **2** Drape, **3** Moisten, **4** Tender, **5** Right, **6** Jumanji, **7** Wurst, **13** Dont ask, **15** Nutella, **16** Obscene, **17** Weaver, **18** Ferry, **19** Strep, **21** Sci-fi

### #45 Square differences *Solution*

You can express the number 9 as a difference of two squares like this: $5^2 - 4^2 = 25 - 16 = 9$. The white squares in the table show numbers between 1 and 30 that can also be written as the difference of two squares (some in more than one way). The shaded numbers are impossible, and in general, numbers that are 2 greater than a multiple of 4 (2, 6, 10, 14, 18...) cannot be written in this way.

| | | | | | |
|---|---|---|---|---|---|
| 1 | 6 | 11 | 16 | 21 | 26 |
| 2 | 7 | 12 | 17 | 22 | 27 |
| 3 | 8 | 13 | 18 | 23 | 28 |
| 1 | 9 | 14 | 19 | 21 | 29 |
| 5 | 10 | 15 | 20 | 25 | 30 |

## Quantum loving

**The Netflix show *Love Is Blind* had rather passed Feedback by. It's a dating show in which participants aren't allowed to see each other face to face and only communicate by voice. Only if they get engaged are they allowed to meet in person.**

**Like so many reality shows, it bills itself as a "social experiment", which is an interesting way to describe televising something so personal for entertainment, but we are sure Netflix's consent forms are impeccable.**

**We bring this up because season seven, released in October, featured a quantum physicist. Garrett Josemans is a technical program manager at IonQ, which is developing "next-generation" quantum computing systems.**

**According to a company blog post promoting his experience, he said: "The opportunity to focus on love in a structured setting was intriguing." That's one way to put it. Josemans added: "My intellectual curiosity kicked in, and it felt like fate knocking on my door."**

**Evidently he was right: Josemans is now married to fellow cast member Taylor Krause. As one of my colleagues in the news department noted, being comfortable with two confusing and conflicting realities existing at once is probably a boon in some relationships.**

## Maxximum stink

Speaking of dating, Mrs Feedback draws our attention to pheromone maxing, sometimes spelled maxxing. This is apparently something that alpha males do.

Actually, let me stop you right there. Alpha males are not a thing. The concept comes from research on captive wolves in the 1940s, which found that a single male would often dominate the pack. From there, the concept spread into popular culture. However, it turns out that wild wolves don't behave like this: their packs are more like extended families. Wolf researcher L. David Mech has spent much of his career trying to correct the record, including attempting to get one of his own early books taken out of print.

Where were we? OK, so human alpha males (which don't exist) have come up with a novel strategy to attract women as sexual partners. They stop showering and wear the same clothes for several days, thus maximising their "musk" and generating an alluring cocktail of pheromones that will, we guess, drive women into a sexual frenzy.

The idea gained a certain amount of internet fame after a teenaged TikTok user posted a video about his experiments, which began: "First off, I'm not stinky. I'm pheromone maxing." A follow-up video, from his mother, asked other parents for advice on how to get him to take a shower.

Feedback isn't quite sure where to start. Maybe with the idea of human pheromones? It's true that some animals communicate by releasing chemicals called pheromones into the air, some of which play a role in mating. However, despite decades of research, there is no definitive evidence that human pheromones exist. It is a bold choice to base your dating strategy around a phenomenon that may not be real.

Even if human sexual pheromones do exist, why would avoiding showering maximise your output? And why would the pheromones cancel out your other smells?

It has been a long time since Feedback played the dating game, but our foggy memories suggest the best way to connect with people was talking to them, finding shared interests and being nice. Still: young minds, fresh ideas.

## Twisteddoodles *for New Scientist*

**Got a story for Feedback?**
**Send it to feedback@newscientist.com**
**or New Scientist, 9 Derry Street, London, W8 5HY**
**Consideration of items sent in the post will be delayed**

## TED talk trouble

**Feedback has never given a TED Talk – our invitation probably got lost in our spam folder – but the idea is to get the best and brightest to communicate their ideas to a wide audience. CRISPR pioneer and Nobel prizewinner Jennifer Doudna has done two TED Talks. Malcolm Gladwell, of *The Tipping Point* fame, has done four, so we guess he's twice as important.**

**However, the need for a never-ending fire hose of content necessarily leads to scrabbling around for material – Feedback knows this feeling all too well – and so we come to a talk given by Raymond Tang. He delivered it in 2017, but TED Conferences's social media reshared it in October, when Feedback encountered its profound wisdom for the first time.**

**Tang was at the time an IT manager for a financial services company. However, his talk is about "lessons from the philosophy of water". You see, by studying how water behaves, we can find fulfilment in our own lives. This sort of thing makes Feedback's brain feel scratchy, so we will give you a few examples of what was on offer.**

**"If we think about water flowing in a river, it is always staying low," says Tang. Yes, liquids under gravity do tend to do that. "Water is open to change. Depending on the temperature, it can be a liquid, solid or gas... We, too, are expected to constantly reinvent and refresh our skills to stay relevant." Feedback appreciates the comparison between the state of the job market and the experience of being boiled and frozen. Truly, water exemplifies the hustle mentality. #grind**

**Let's set aside the obvious fact: that you could get similar advice from one of those internet memes that emboss an "inspirational" phrase onto a photo of a waterfall. The real trouble with advice like this is that it is never as universally applicable as the speaker claims. Many hands might make light work, but too many cooks spoil the broth. We hereby pitch our TED Talk: "It depends".**

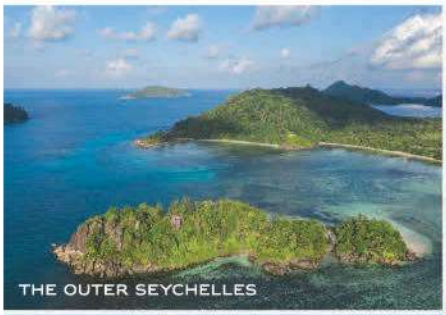
# ‘Bel Can-do’

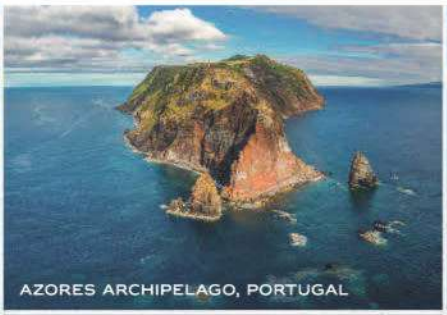
**In November 2022 we introduced the Bel Canto.** Instantly making haute horology accessible. This subtly chiming timepiece caused a cacophony. And enormous demand. (The first 600 sold out in 8 hours.) Asked could we produce 5,000 annually, our Swiss CEO Jorg Bader Snr replied: “No. But we’ll find a way.” Because that is our way. Today, our supply chain is as fit for purpose as the gear chain of the new Bel Canto Classic. Which features a dressed-up dial. A dialled-down handset. And a gorgeous guilloché finish, with a precision only achievable (and affordable) using a femto laser. Outward displays, we like to think, of inward grace.

**(Bel Can-)Do your research**

Christopher Ward

christopherward.com


THE OUTER SEYCHELLES


AZORES ARCHIPELAGO, PORTUGAL

FLORIDA GULF COASTLINE, UNITED STATES

SYLVIA EARLE EXPLORES
COCOS ISLAND, COSTA RICA

THERE ARE OVER 130
HOPE SPOTS GLOBALLY

SYLVIA EARLE WITH VOLUNTEERS,
THE OUTER SEYCHELLES

GREAT BARRIER REEF, AUSTRALIA

MOBULA RAYS, AZORES
ARCHIPELAGO, PORTUGAL

SEA LION,
GALÁPAGOS,
ECUADOR

MISSION BLUE

# ON OUR WATCH

**Hope can now be spotted across all our planet's seas and oceans.** Sites are made into aquatic havens by local communities, to safeguard the richness and diversity of the ecosystems they depend on. Sylvia Earle's invaluable experience as an explorer and marine biologist continues to help further their goal, through her organisation, Mission Blue. Together, they have created over 130 Hope Spots and counting. Carrying a message of hope for generations to come. It is that vision, that dedication to a perpetual planet, which we are proud to stand by. **For as long as it is needed.**

*Rolex supports Mission Blue in its commitment to protecting 30% of the oceans by 2030.*

*#Perpetual*

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